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Cameroon-Nigeria-Italy scientific cooperation:  
veterinary public health  
and sustainable food safety  
to promote "one health/one prevention"



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Edited by C. Frazzoli,  
E.A. Asongalem and O.E. Orisakwe

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**ISTITUTO SUPERIORE DI SANITÀ**

**Cameroon-Nigeria-Italy scientific cooperation:  
veterinary public health and sustainable food safety  
to promote “one health/one prevention”**

Edited by  
Chiara Frazzoli (a), Emmanuel Acha Asongalem (b)  
and Orish Ebere Orisakwe (c)

*(a) Department of Veterinary Public Health and Food Safety, Istituto Superiore di Sanità, Italy  
(b) Faculty of Health Sciences, University of Buea, Cameroon  
(c) Faculty of Pharmacy, University of Port Harcourt, Nigeria*

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2012, vi, 198 p. Rapporti ISTISAN 12/49

Sub-Saharan Africa has often adopted a short-term view of human development relying on external financial support, whereas limited resources are invested in scientific research, technology, prevention and innovation as drivers of social and economic growth and long-term sustainable development. In a continent where products of animal origin have become fundamental in human diet, veterinary public health and food safety are called to face toxicological risk factors related to food-chain contamination, in particular those triggering poor health burden through vertical (mother to child) exposure. This report summarizes the current items of the Cameroon-Nigeria-Italy experience of scientific cooperation pivoting on a network crosscutting public institutions, universities, NGOs and social, professional and scientific organizations. The network promotes a “social toxicology” based on the proactive capability of local communities to widen the field of international cooperation to the prevention early in life of chronic multi-factorial diseases. This will contribute towards the mitigation of infant morbidity and mortality, the increase of healthy life expectancy in children and adults as well as the achievement of the Millennium Development Goals.

*Key words:* Toxicology; Transgenerational exposure; Translational prevention

Istituto Superiore di Sanità

**Cooperazione scientifica Camerun-Nigeria-Italia: la sanità pubblica veterinaria e la sicurezza alimentare sostenibile per la promozione della “one health/one prevention”.**

A cura di Chiara Frazzoli, Emmanuel Acha Asongalem e Orish Ebere Orisakwe

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L’Africa sub-sahariana ha spesso adottato una visione a breve termine dello sviluppo umano, ricorrendo al sostegno economico esterno e investendo poco in ricerca scientifica, tecnologia, prevenzione e innovazione come propulsori di crescita sociale ed economica e sviluppo sostenibile a lungo termine. In un continente in cui i prodotti di origine animale sono diventati fondamentali nella dieta, la sanità pubblica veterinaria e la sicurezza alimentare sono chiamate ad affrontare i fattori di rischio tossicologici della contaminazione delle filiere alimentari, in particolare quelli rilevanti per la salute della generazione futura. Il rapporto riepiloga gli elementi dell’esperienza di cooperazione scientifica Camerun-Nigeria-Italia imperniata su un network trasversale fra istituzioni pubbliche, università e organizzazioni sociali, professionali e scientifiche. Il network promuove una “tossicologia sociale” basata sulla capacità proattiva delle comunità locali per ampliare il campo della cooperazione internazionale alla prevenzione dei fattori precoci di rischio delle malattie multifattoriali croniche. Ciò contribuirà all’attenuazione della morbilità e mortalità infantile e all’incremento dell’aspettativa di vita in salute di bambini e adulti, nonché al raggiungimento dei *Millennium Development Goals*.

*Parole chiave:* Tossicologia; Esposizione transgenerazionale; Prevenzione traslazionale

This report stems from the activities of the ‘Nutrition & food safety and wholesomeness. Prevention, education and research Network’ (Noodles.onlus, [www.noodlesonlus.org](http://www.noodlesonlus.org)).

Per informazioni su questo documento scrivere a: [chiara.frazzoli@iss.it](mailto:chiara.frazzoli@iss.it)

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## **PREFACE ON THE ITALIAN SCIENTIFIC COOPERATION IN CAMEROON**

Modern Cameroon is the result of a series of complicated historical phenomena: half a century of independence has made it possible to stabilize the unity of a country which is to be considered, from an ethnical, social and linguistic point of view, extremely complex and diverse.

Such a unity has also been reached thanks to a refined balance among the different people and regions and through a subtle (and careful) system of power distribution.

Amid the most important results achieved in the past 50 years, great importance has been given by the Government to the population's social and economic development.

As a consequence, all kinds of cooperation in the field of maternal neonatal health between the Istituto Superiore di Sanità (ISS, the National Health Institute in Italy), the Consiglio Nazionale delle Ricerche (CNR, the National Research Council) and selected Cameroonian partners, among which are the Pasteur Centre, the University of Buea, the University of Yaounde' and the University of Dschang, are greatly appreciated.

I hope that the projects described in this volume, intended to increase both cooperation and research in the neonatal sector, will soon be financed. In the meantime, my applause to the exceptional – and not always easy – work carried out in the field by the researchers.

Stefano Pontesilli  
*Ambassador of the Italian Republic in Cameroon*





## **PREFACE ON THE ITALIAN SCIENTIFIC COOPERATION IN NIGERIA**

The Italian cooperation in favour of Nigeria has its roots in years of commitments for the development, in the first place, of the human factor of this country. The targets that Italy has constantly aimed at are to allow the creation of better living conditions, particularly for the most vulnerable parts of the Nigerian population. At the same time, Italy has meant to recover lost professional skills in the fields of agriculture, craftsmanship and small-medium entrepreneurship, particularly starting from the 60s when the economy of the country has become more and more dependent on the hydrocarbons sector.

The Italian interventions in the fight against human trafficking, for the protection of human rights, for the assistance to the neediest, for the improvement of the health, education and vocational training systems, are all in line with the Millennium Development Goals of the United Nations, and they help Nigeria in its efforts for their fulfilment. Moreover, Nigeria has set the ambitious goal to be among the 20 most developed economies in the world by the year 2020. An import prerequisite to achieve the afore-said result is certainly to enjoy adequate infrastructures and fully trained and skilled people in the mentioned fields.

I would like to underline the importance of the work of the many Italian non governmental organizations that are engaged in Nigeria also thanks to contributions from the Ministry of Foreign Affairs. They egregiously contribute to the implementation of remarkable projects in the fields of health, education and vocational training. They also allow establishing fruitful relations and collaborations with Nigerian organizations and other entities, thus strengthening also on this side the links between Nigeria and Italy.

Generally, the links between Nigeria and Italy are rooted in the past decades when many Italians established themselves in this country opening important and much appreciated companies. Besides, we have to consider the significant Nigerian community living and working in Italy. Such close relations are continuously refreshed thanks to the attention that Italy pays to the socio-political and economic dynamics of the Federal Republic of Nigeria and are strengthened by reciprocal high level visits.

We are conscious of the challenges that await the most populous African State in fulfilling the commendable objectives of growth and development that it wishes to achieve.

Among the issues to be solved, there is the still high level of infant and maternal mortality and the too low life expectation.

Tuberculosis, HIV/AIDS, malaria and cancer continue to afflict the population, particularly in the rural areas where the access to health service is scarce as well as the hygienic conditions. Illnesses that are basically harmless in other parts of the world, like measles, are unfortunately still lethal among infants.

Poor and minimum hygienic conditions and education on food security and personal hygiene are basically the reason of periodical, though limited, cholera outbursts. The education system, notably the secondary one, suffers of a poor capability of renewal and of keeping itself up-to-date.

Conscious of the utmost importance to win the above challenges, the Nigerian Government has undertaken several initiatives for the sake of which the support of the International Community will remain important. A support not only in financial terms but rather in terms of technical assistance and know-how transfer for mobilizing the high human and economic potentials intrinsic in the diversified composition of the Nigerian society and in the rich resources enjoyed by this land.

Italy will maintain its proper role in this process, both on the bilateral context and as a member of the European Union, whose joint and coordinated efforts, together with other important actors, are already fostering essential synergies for a sustainable growth on a wide scale.

We hope that Nigeria will soon be able to enjoy new significant results.

Roberto Colaminè  
*Ambassador of the Italian Republic in Nigeria*

## INTRODUCTION

Chiara Frazzoli (a), Emmanuel Acha Asongalem (b), Orish Ebere Orisakwe (c)

(a) *Department of Veterinary Public Health and Food Safety, Istituto Superiore di Sanità, Italy*

(b) *Faculty of Health Sciences, University of Buea, Cameroon*

(c) *Faculty of Pharmacy, University of Port Harcourt, Nigeria*

This document reports the experience of a Cameroon-Nigeria-Italy research network. The Network “Nutrition & food safety and wholesomeness - Prevention, education and research network”, or NOODLES for short (<http://www.noodlesonlus.org>), stems from the Congress of the African Society for Toxicological Sciences (ASTS) held in Limbe, Cameroon, in 2006, and it has been registered as no-profit organization of social utility under the Italian law since 2008. NOODLES aims at contributing to bridge the scientific exchange between Europe and Africa towards the translation of scientific knowledge into local proactive policy.

The network pivots around some core concepts. In particular, Sustainable Food Safety is defined as *the complex of actions intended to minimize adverse health impact on future generation associated to today's safety of foods and nutritional quality of diet* (1). Pre-natal and neonatal prevention will impact not only on infant morbidity and mortality rates, but on the disparities in the chance for a healthy adulthood; under this respect analysis of toxicological co-factors is critical for the actual ability of the (global) society to protect progeny health in countries without broad, stable regulatory and protective measures in place.

The ubiquity of food in life suggests food safety as prime issue of knowledge translation; new research in multiple aspects of food-chain safety, from farm to fork, must be incorporated into practice to prevent chronic multi-factorial diseases (2). Food safety and risk assessment constitute novel aspects in the general scenario of international cooperation to development, needing a 360° approach based on the awareness that food come from living organisms.

Food and Agriculture Organization of the United Nations, World Health Organization and World Organisation for Animal Health define Veterinary Public Health (VPH) as *the contributions to the physical, mental and social well being of humans through an understanding and application of veterinary science* (3). In many African countries the control of classical zoonoses is currently the core issue of VPH, also considering that the organization of veterinary services is often poor or almost absent. VPH builds up tools to understand, prevent and control manageable aspects of zoonoses, according to a strategy of “translational prevention” (from bench to risk assessment).

In a continent where products of animal origin have become fundamental in human diet and many counties are developing intensive agriculture and animal rearing, VPH and food safety are called to face environmental and dietary toxicological factors triggering poor health burden, in particular those occurring through vertical (*i.e.* transgenerational) exposure, under a One Health/One Prevention scheme.

The Network joins multidisciplinary competencies crosscutting public institutions: Centre Pasteur, Cameroon; Istituto Superiore di Sanità, Italy; Agenzia Regionale per lo Sviluppo e l'Innovazione dell'Agricoltura del Lazio (ARSIAL), Italy; Consiglio Nazionale delle Ricerche (CNR, the National Research Council), Italy; universities (University of Yaoundé, Cameroon; University of Buea, Cameroon; University of Dschang, Cameroon; University of Port Harcourt, Nigeria); scientific societies and networks (the West Africa Society of Toxicology, WASOT; the Cameroon Society for Toxicological Sciences, CSTS; and the Italian network for folic acid promotion); women' organizations (the Italian organization of Senegalese women, DEGGÒ);

professional organizations (the Senegalese association of Senegalese midwives, ANSFES; and the Italian association of wellness chefs, Cucina Wellness); producers' organizations (the Italian breeders association: Associazione Italiana Allevatori, AIA); and informal and formal education (the Cameroonian non-government organization Integrated Health for all Foundation, IHAF; and the Italian University Master in Human Development and Food Security, HDFFS).

The report is structured in two parts:

– *Part A. Conceptual framework*

It details the conceptual framework of the research activities. This part calls for a comprehensive appreciation of food-related issues (environment, health, society, ethics, economy and culture) as a major component of prevention. Since human health, animal health and environmental health are linked, chemical/toxicological aspects of health risks are recognised as emerging public health problem in Africa. The high morbidity and mortality of child under five years in Africa has a multifactorial origin, but limited attention has been given so far to environmental factors. As an example, the mitigation of risks from endocrine disrupters (webpage of the Istituto Superiore di Sanità, <http://www.iss.it/inte/?lang=2>) can contribute promoting mother-child health, protecting growth and development. Innovation is pivotal to protect food chains, through efficient and up-to-date risk assessment and management systems from the primary production steps, such as the living environment and water resources for food-producing animals, and manageable hotspots in feed-food chains. VPH and food safety should operate according to actual feasibility and sustainability, also considering policy and requirements of national and international trade as well as the chances given by the emerging African market. Innovation means also development of transferable biomarkers and relevant diagnostics technology for low-cost implementation of novel HACCP strategies inclusive of toxicological risks along food chains; the new tools should be implemented also to develop and assess risk management/reduction/bioremediation actions. Primary prevention at food production chain level can be integrated by biomonitoring; this is pivotal to disclose actual human total exposure and discriminate the impact of diet from Total Diet Studies data. Native remedies are investigated according to their possible role in body burden detoxifying protocols, in order to mitigate health effects of populations exposed to toxicants. Finally, poor perception and understanding of health risks related to toxic exposures call for population empowerment (especially the young age groups), thus creating health education initiatives and spreading health enhancing behaviour.

– *Part B. African scenarios: case studies*

It collects specific experiences following the food-chain (environment-farm-fork) criterion. Water bodies are one basis of food chain: increasing urban and peri-urban animal and human populations call for integrated requirements to protect water supplies (potable and recreational water reservoirs such as lakes, rivers, even swimming pools) against contamination. The need of integrating VPH expertises in environmental management becomes evident in the widespread waste issues, including the safe disposal of animal carcasses and manure. The role of products of animal origin in human nutrition and diet has become fundamental; zoonoses may be an important factor in hampering food security; on the other hand, the control of zoonoses reassures the African consumer - often more prone to assign safety to foods imported from developed economies- thus facilitating local food productions, diminishing the dependence from importation and improving local economy. In order to promote local productions, nutritional and safety aspects should be assessed for locally produced ingredients, foods such as underused crops' varieties and meals: therefore, a science-based risk-to-benefit approach should be

implemented. Moreover, Total Diet Studies are pivotal to assess exposure pathways to both essential micronutrients and toxic contaminants in different Countries or regions, according to natural (e.g. geological) and anthropic (e.g. cultural, economic) factors. Risk to benefit assessment of active principles, local supplements and syrups is also needed, especially those devoted to child and women of fertile age, to evaluate background exposure: native culture and medicine may be a good source of products with both nutritional and healing value. The African consumer may be vulnerable also due to poor information: potentially hazardous products banned in developed economies may be dumped in Africa in the absence of proper legislation. In general, addressing capacity-building problems depends largely upon the implementation of proactive measures. Non-governmental organizations may act as agile tools to implement programmes of education of health operators, teachers and general population through formal and informal capacity building, whereas the promotion of both access and production of scientific literature allow the empowerment of scholars of both Academic and Public Research Bodies.

The Network contributes the efforts to bridge the international scientific gaps between European and African countries as well as between different African Countries that historically have had limited scientific contact in the fields dealt with by this Report: this interdisciplinary, horizontal and vertical cooperation between human, animal and life sciences under the “One Health/One Prevention” umbrella is challenging and complex. But feasible.

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**PART A**  
**Conceptual framework**





# SCIENTIFIC RESEARCH IN VETERINARY PUBLIC HEALTH AND FOOD SAFETY AS DRIVER FOR DEVELOPMENT

Orish Ebere Orisakwe (a), Emmanuel Acha Asongalem (b), Chiara Frazzoli (c)

(a) *Faculty of Pharmacy, University of Port Harcourt, Nigeria*

(b) *Faculty of Health Sciences, University of Buea, Cameroon*

(c) *Department of Veterinary Public Health and Food Safety, Istituto Superiore di Sanità, Italy*

## Framework

The Millennium Declaration set 2015 as the target date for achieving the eight Millennium Development Goals. These goals established quantitative benchmarks for halving extreme poverty in all its forms:

Goal 1: Eradicate extreme poverty and hunger

Goal 2: Achieve universal primary education

Goal 3: Promote gender equality and empower women

Goal 4: Reduce child mortality rates

Goal 5: Improve maternal health

Goal 6: Combat HIV/AIDS, malaria, and other diseases

Goal 7: Ensure environmental sustainability

Goal 8: Develop a global partnership for development

The African continent has often adopted a short-term view of human development, persisting in a reliance on external financial support, which often targets short-term goals. As a result, the continent has failed to invest in science, technology and innovation as drivers of economic growth and long-term sustainable development (1).

Africa south of the Sahara is the least developed region of the world. It includes 23 out of the 35 poorest countries in the world and, for many of these – despite years of intensive international effort – economic and social conditions show little real improvement and, in some cases, have even deteriorated. Sub-Saharan Africa is not, of course, a homogeneous entity. Consisting today of 45 independent nation States, it includes, at one extreme, South Africa, large, rich, and highly developed, and at the other, tiny island states like Sao Tome and Principe or the Seychelles with populations of well below 100,000. The range in between is no less varied, covering countries like the Sudan, with a land area of 2.5 million sq. km and a population of some 19 million, Nigeria, with slightly less than 1 million sq. km and over 140 million inhabitants, and the drought-prone countries of the Sahel, where the balance between land resources and people grows ever more precarious.

A tenacious urgency underlies most sub-Saharan African affairs. In particular, the matters of health and environment stand perpetually pregnant with disaster. Although simultaneously progress is desirable on all fronts, it is important to establish priorities for the agents of research and development. What measures should the ranking of the many environmental challenges facing the sub-Saharan Africa and its peoples be based on? Is this measure the number of individuals who are affected by hazardous environmental conditions, in terms of morbidity and mortality, or the impacts on their quality of life? What about the vulnerability of forests and wildlife that attract many of the world's influential citizens to visit sub-Saharan Africa?

According to the World Health Organization's (WHO) recent comprehensive study on the Environmental Burden of Disease (EBD), 2.97 million people die every year in all 46 African countries because of environmental risk factors (2). Most of these deaths are preventable because they are associated with water quality, sanitation, and hygiene. Air quality is also a major risk factor. These are very broad categories, and it is important to dissect the constituents of sub-Saharan African water and air that make them so deadly. Perhaps even more than the knowledge of biological and chemical pollutants, which is described very richly in the academic literature, the question may be rooted in the recalcitrance of human behaviour and implementation of technology. For instance, out of the 46 African countries included in WHO's EBD study, only six countries (Cameroon, Democratic Republic of Congo, Eritrea, Ghana, Malawi, and Mauritania) have unequivocally eliminated the use of lead (Pb) in gasoline. This is a point of concern, all the more by considering the import/dumping of vehicles equipped with catalytic devices. The dangers of Pb in water, soil, and air are certainly no secret, and there are ample technological tools to get rid of it to ensure that sub-Saharan African children should no longer be exposed to this deadening metal. An old Pb mine in Kabwe Zimbabwe is the only African location on the list of top ten "worst polluted sites on Earth" (3), but the pervasiveness of Pb poisoning affects everyone on the continent.

Depending on the country, controllable environmental hazards contribute from the lowest proportion of 13% (Botswana) to the highest proportion of 37% (Angola) to the total burden of disease and disability (Table 1).

Among the multiple pathways of exposure, ingestion is particularly significant; in fact, although still not quantified, the transgenerational diet, i.e. the vertical (mother to child) transmission of the risk of chronic diseases in the adulthood, is a prevention point deserving immediate attention (4).

This environmental burden of disease is unacceptably high level, giving the scientific resources and technological knowledge available globally and in sub-Saharan Africa. For example, one of the most obvious environmental problems encountered by first time visitors to large urban centres in Africa is the sheer obscenity of solid waste and inefficient urban run-off systems. Most modern cities have solved this problem, although in a way that encourages waste dumping rather than recycling (5). Instead of developing innovative ways of solid waste management on the continent, many sub-Saharan African countries occasionally import hazardous solid waste disguised as potentially useful "second-hand" products that end up polluting air and water, despite the best intentions of the Basel Convention on the control of transboundary movements of hazardous wastes and their disposal, which is touted as the most comprehensive global environmental agreement on hazardous and other wastes (6). The open air incineration and dumping of solid waste contribute major hazards associated with environmental pollution, with expected implications for food production chains and human health (7).

The recognized difficulty in developing economies in managing health problems during rapid development along with the increase of chronic multi-factorial diseases in Africa involves environmental and dietary exposures, whose role is still under-recognized. For instance, the demand for food of animal origin is rapidly increasing with growing urban settings and much attention is therefore rightly devoted to zoonoses caused by transmissible agents passing from animals to humans.

"One health" has been defined as "the collaborative effort of multiple disciplines-working locally, nationally, and globally – to attain optimal health for people, animals and the environment" (8).

**Table 1. Rank order of African countries based on the comparative impact of environmental risk factors on disease burden (3)**

Country	Annual deaths from environmental diseases	Environmental disease burden as % of total disease burden
Angola	116000	37
Mali	85000	35
Benin	29000	34
Burkina Faso	83000	34
Niger	86000	34
Democratic Republic of Congo	325000	33
Mauritania	13000	33
Sierra Leone	44000	33
Madagascar	66000	32
Chad	46000	31
Guinea-Bissau	8200	31
Rwanda	40000	31
Senegal	32300	31
Gambia	4700	30
Liberia	21000	30
Comoros	1600	29
Guinea	34000	29
Nigeria	581000	29
Cameroon	65000	28
Eritrea	11000	28
Ethiopia	300000	28
Mozambique	108000	28
Togo	17000	28
Burundi	32000	27
Cote d'Ivoire	68000	27
Equatorial Guinea	2000	27
Ghana	56000	27
Malawi	68000	27
Sao Tome and Principe	350	27
United Republic of Tanzania	155000	26
Central African Republic	19000	25
Zambia	58000	25
Algeria	42000	24
Kenya	94000	24
Cape Verde	600	23
Congo	10000	23
Gabon	3400	23
Seychelles	100	19
Mauritius	1300	18
Namibia	4700	17
Swaziland	4300	17
South Africa	109000	16
Uganda	109000	16
Zimbabwe	44000	15
Botswana	5000	13

The development of “one health/one prevention” induces the development of Veterinary Public Health (VPH): globally, zoonoses control and food hygiene have experienced a dynamic expansion consequent to the increase of knowledge and social and economic evolution. VPH enlarges its field of application to include health risks associated to dietary exposure through exposed food producing animals, including toxicological risk factors in infectious diseases

aetiology and prevention, with important scientific, social and political implications (9). According to this intuition, in 2000 Prof. Adriano Mantovani enlarged the definition of zoonoses to “any detriment to the health and/or quality of human life deriving from relationships with (other) vertebrate or edible or toxic invertebrate animals” (10). Moreover, communities have different characteristics and therefore different priorities and needs depending on specific factors such as population density, social and economic structure, co-existence of ethnic and religious groups, cultural beliefs, mean age, mean income, availability of roads or distance from large roads and cities, local health problems due to traditions and way of life or climatic conditions, etc. Following this approach, Prof Adriano Mantovani likes representing VPH (and generally public health, according to the concept of “one medicine”) as an umbrella protecting the human population (consumers, producers, population at large) and the animals of different categories from a series of risks, that he lists (11) as follows (in alphabetical order):

- biological food contamination;
- chemical food contamination;
- economical losses;
- emergencies (epidemic and not epidemic);
- environmental contamination;
- human conflicts involving animals;
- human/animals conflict;
- improper human nutrition;
- improper legislation;
- infections of immunocompromised persons;
- nuclear food contamination;
- occupational diseases;
- pharmaco-resistance;
- poor education;
- zoonoses.

### **Activity and perspectives of scientific organizations in Africa**

Scientific organizations representing the research community have the role of developing educational and training activities and materials to improve the integrity of research. The Cameroon Society for Toxicological Sciences (CSTS) is a five-year-old organisation responsible for promoting toxicological research and awareness in Cameroon and Central Africa sub region in general. The members have come to realize that advertent or inadvertent chemical exposure is contributing significantly to the increased morbidity and mortality rates in Cameroonian society today. These cocktails of chemicals found in foods, air and water, may culminate to diseases such as cancer, organ damage, hypertension and diabetes.

CSTS goals are to sensitize the government and the populace on the importance of Toxicology (chemical toxicity and their health consequences) on our daily lives through conferences, seminars, workshops and symposia.

CSTS has hosted three scientific conferences, workshops and basic toxicology training in Buea (2007), Dschang (2009) and Buea (2011). From the 31<sup>st</sup> May - 3<sup>rd</sup> June 2011, a Joint International Toxicology Conference co-hosted with Society for Environmental Toxicology and Chemistry (SETAC) and Africa Education Initiative (NEF) was held in the University of Buea with over 230 participants from 18 different countries located in the 5 continents. Its success was praised both nationally and internationally and has engendered CSTS to be forward

looking. CSTS achieved most of the goals during this conference following the 2010 roadmap. In 2010, CSTS devised a 5-year roadmap as follows:

- Organise its biannual conferences (2011, 2013 and 2015) and invite international experts to deliver lectures and presentations. The next conference is in 2013 in Yaoundé.
- Organise talks and symposia in 2012 and 2014 on contemporary toxicology issues affecting the country.
- Continue to offer its annual toxicology short talks to schools anywhere in the country. CSTS has videos which have been offered freely by World Library of Toxicology.
- Collaborate with some Cameroonian Universities to carry out certificated short courses in Toxicology.
- Host a Risk Assessment Summer School (RASS) in 2014 – an International Toxicology School held yearly round the world.

As of now CSTS is planning to give a talk on chemical effects to students in the Government Bilingual College Buea in May 2012. The contribution to toxicological information shall be disseminated through the websites ([www.cameroonocietyfortoxicologicalsciences.org](http://www.cameroonocietyfortoxicologicalsciences.org)) and the journal ([www.ajtscm.org](http://www.ajtscm.org)) also aimed at developing policies to promote responsible authorship practices. CSTS is making progress in its ambition to promote health in Cameroon, hoping that in the next few years activities will be able to change the lives of citizens of the sub region.

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## TOXICOLOGY IN AFRICA

Orish Ebere Orisakwe

*Faculty of Pharmacy, University of Port Harcourt, Nigeria*

### Modern environmental health hazards

According to the World Health Organization (WHO), about one-third of Africa's disease burden is attributable to environmental hazards (1). The major contributing risk factors to environmental disease burden in the continent are traditional environmental health hazards such as lack of access to safe water, indoor air pollution from solid fuel combustion, and lack of sanitation and hygiene. However, with notable economic growth the past decade (2), urbanization, and continuing industrialization, Modern Environmental Health Hazards (MEHs) can be expected to eventually emerge and perhaps supersede traditional hazards as critical contributors to environmental disease burden in the continent. The transition to MEHs is in progress, as evidenced by the combination of preindustrial and industrial era environmental health issues confronting many African communities (3). Assuring population health and well-being in the near future, therefore, will depend not only on how well traditional hazards and risks are managed but also on the degree to which MEHs and their potential impacts are prevented or controlled.

Particular socio-ecological and climatic factors also contribute to high levels of inhalation and ingestion of lead-laden aerosol and dust (4, 5).

Excessive use of alcohol and tobacco, exclusive use of wells as sources of drinking water, and high consumption of the Nigerian table salt may all constitute environmental pathways for increased lead burden (6). In many parts of Nigeria, self-employed adults often sell agricultural or textile goods at the market. Marketplaces are crowded and dusty, with numerous automobiles with poor exhaust systems and powered by leaded gasoline. Those who ply their trade in these areas are likely to suffer lead exposure.

Traditional medicine is still an important component of the health care system in Nigeria. Studies have shown high levels of heavy metals, especially lead, in Nigerian herbal remedies, irrespective of registration by the relevant regulatory authority (7). Beverages commonly consumed in Nigeria, including sachet water and various other canned and non-canned beverages, have been found to contain lead above the US Environmental Protection Agency permissible level (8, 9).

Although there is a general belief that the most common cause of infertility in Nigeria is infection (10), there are many cases where infections have been treated without correction of infertility (11). In Nigeria there are higher rates of irreversible oligo- or azoospermia than most other causes of infertility, and fewer resources for the management of infertility than in many other nations (12). What is responsible for the over twelve million infertile persons in Nigeria is largely unknown, but may be nutritional and environmental. Adebamowo and colleagues used a focus group approach to examine knowledge, attitudes, and practices related to lead exposure in South Western Nigeria. They found that participants had limited awareness of the sources of lead exposure in the domestic environment and little knowledge of the health effects of chronic low dose lead exposure.

Lead exposure is a major health risk factor in all Nigeria communities, both rural and urban. Prevention remains the best option for reducing lead exposure. The high blood lead levels seen

in non-occupationally exposed in various studies conducted at different times and in various parts of Nigeria underscore the extent of environmental lead pollution in Nigeria. High BLLs in the same population cast doubt on the ease of sourcing “real unexposed control subjects” in future studies.

### **Indoor air pollution**

Sentences like “Smoke from indoor cooking fires kills one person every 20 seconds in the developing world”, “Smoke in the home kills more people than malaria does, and almost as many as unsafe water and sanitation”, “2.4 billion people burn biomass (organic matter) for cooking and heating, and when coal is included, 3 billion people - half the world’s population – rely on solid fuel”, and “Smoke in the home is the fourth greatest cause of death and disease in the world’s poorest countries, killing 1.6 million people annually. Nearly a million of them are children. Most of the rest are women” justify real concern. Biomass accounts for more than one-half of domestic energy in many developing countries and for as much as 95% in some lower income ones (13, 14). There is also evidence that in some countries the declining trend of household dependence on biomass has slowed, or even reversed, especially among poorer households (15, 16). Biomass and coal smoke contain a large number of pollutants and known health hazards, including particulate matter, carbon monoxide, nitrogen dioxide, sulfur oxides (mainly from coal), formaldehyde, and polycyclic organic matter, including carcinogens such as benzo[*a*]pyrene (17-21). Exposure to Indoor Air Pollution (IAP) from the combustion of solid fuels has been implicated, with varying degrees of evidence, as a causal agent of several diseases in developing countries, including Acute Respiratory Infections (ARI) and otitis media (middle ear infection), Chronic Obstructive Pulmonary Disease (COPD), lung cancer (from coal smoke), asthma, cancer of the nasopharynx and larynx, tuberculosis, perinatal conditions and low birth weight, and diseases of the eye such as cataract and blindness (21-24).

Most current epidemiologic studies on the health impacts of exposure to IAP in developing countries have focused on the first three of the above diseases (21, 22). Increasing evidence of the role of maternal exposure to IAP as a risk factor for low birth weight (25) illustrates that perinatal/neonatal conditions, in particular low birth weight, are also likely to have large and long-term health effects and to be an important source of burden of disease due to this risk factor. Given current quantitative knowledge, however, Acute Lower Respiratory Infections (ALRI) and COPD are the leading causes of mortality and burden of disease due to exposure to IAP from solid fuels.

More detailed research on exposure to indoor smoke and its impacts on respiratory diseases in Nigeria began in the late 1960s (26).

### **Environment health in sub-Saharan Africa**

Environmental degradation, due to the concurrent effects of old and new agents, is one of the major causes responsible for the worsening of the health problems in sub-Saharan Africa (27-28). Traditional lifestyles, such as burning wood or trash for energy production, or excessive goat raising, can be very destructive and polluting when practiced in the context of large human agglomerations. Unchecked urbanization, generally associated with lack of housing and sanitary infrastructures, increases the chances of transmission of infectious diseases, as well as exposure to environmental pollutants. Air pollution in major sub-Saharan African cities is more severe than anywhere in the world, due to excessive traffic on poor roads, use of dirty fuels and obsolete

cars. Industrialization, rapidly progressing around many sub-Saharan African cities, is often based on outdated machinery and highly polluting productions, and relies on intensive exploitation of local resources and cheap labour (29). All this contributes to air and water pollution and to disease-related occupational exposures. Turning to agriculture, in most irrigation-suitable areas, export-driven intensive monocultures are rapidly replacing diversified subsistence farming or natural environments, requiring use and abuse of pesticides, which results in severe contamination of waters and food chains (27).

An epidemic of environmental cancers is presently emerging in developing countries (28). In sub-Saharan Africa, cancer is already perceived as a major threat, particularly in women, as exemplified in the review focused on Sudan (30). An important subset of the cancers that occur in Sudan and in Nigeria is infection-related (31). However, it is remarkable that in both Sudan and Nigeria, a type of cancer for which an infectious agent has not been unequivocally identified (i.e., breast cancer) is reported as the most frequent in hospital-based cancer series. This suggests a contribution of other etiologic factors including genetic predisposition, reproductive factors as well as environmental pollution.

Evidence is presented here that the breast cancer patients of our study were chronically exposed primarily to Pb and that the level of this exposure was sufficient to abolish the cancer-protecting effects of Se. Effective measures to reduce the lead burden of the population thus must become an essential part of any public health program aiming at reducing the breast cancer risk of Nigerian women (32).

In sub-Saharan Africa detection, prevention, and treatment of hypertension and other diseases associated with oxidative stress should now be regarded as a high priority (33). It is estimated that if the 10–20 million people who are believed to have hypertension in sub-Saharan Africa are detected and treated, about 250,000 deaths would be prevented annually. To this end, toxicological evaluations, diagnosis and prevention of environmental mediated diseases should now be encouraged.

## **Toxicology of artisanal mining and public health in sub-Saharan Africa**

The world community has undertaken various environmental projects involving the monitoring of soil, air, water and aquatic life. There is interest in securing harmony between the industry, on one side, and the environment and human health on the other. For example, in 1991 and 1992, the United Nations University in Tokyo sponsored conferences on industry, environment and human health. It was noted that mercury poisoning poses a serious hazard to health, as was seen in Minamata, Japan. To avoid a repetition of such events, the world community is undertaking early surveys and dissemination of information as a basis for timely action. Action includes international collaborative research on toxic metals. The experience of the Japanese researchers in metal toxicology, particularly in the case of mercury and cadmium poisonings, is most useful to the rest of the world. Uitto (34) correctly noted that the primary concern is to learn from these experiences so as to avoid similar episodes in future and where they have not been avoided, to facilitate community rehabilitation.

Cycles of floods and drought, high prices of farm equipment, and an atmosphere of economic instability have driven millions of farmers in developing countries to abandon subsistence agriculture and take up artisanal mining, a practice which uses rudimentary techniques of mineral extraction and often operates under hazardous conditions. Driven significantly by poverty, Artisanal and Small-scale Mining (ASM) is usually undertaken by



workers with limited understanding of the long-term impacts of their activities on the environment and on their health and with limited capacity to mitigate the hazards.

Artisan mining in sub-Saharan Africa conforms to neither mining laws nor regulations governing mining operations and environmental management. The miners are unaware of the effects of metal poisoning during mining and mineral processing. In principle, artisan mining in sub-Saharan Africa is an informal sector with very little Government control.

Relationships between mining and environment are particularly complex and not yet fully understood especially in developing countries. In Kenya, this complexity is due partly to the level of research and lack of adequate analytical capabilities as well as foolproof diagnostic ability for environmentally related health conditions. Artisanal gold mining is quite volatile, its intensity being a function of socioeconomic conditions of the typical poor regions where it occurs. In fact, the magnitude of Hg emissions from small-scale gold mining correlate inversely with the gross national product of developing countries (35).

The volatile nature of small-scale gold mining can be exemplified worldwide. In Tanzania, for example, poor crop yields and low crop prices for some time have forced many people in rural areas to engage in gold mining as an alternative means for subsistence. In Kadoma, Zimbabwe, it is common to see miners handling a large tablet of sodium cyanide and constantly rubbing it on the copper plates during the operation to remove the “sick spots” (Cu-oxidation areas).

The amalgamation Cu-plates are periodically inspected and, when solid amalgams are identified on the surface, the process is interrupted and amalgam is scraped from the plates. At this stage, miners are exposed to high levels of Hg vapor. The amalgam recovered from the plate is squeezed in a piece of fabric to eliminate excess liquid mercury, and then heated by a gas torch or bonfire or even an electric cooking plate.

These Hg emissions are commonly inhaled by the miners and surrounding population with a broad range of related health effects, as would be expected.

Artisan mining is a dangerous activity as the heavy metals, mainly mercury, lead, and arsenic are released to the environment. According to the United States Agency for Toxic Substances and Disease Registry (36), As, Pb and Hg top the priority list of hazardous substances. The first two are major metals in gold-sulphide deposits, where they occur as minerals mainly in arsenopyrite (FeAsS) and galena (PbS), respectively. Under natural conditions, they are relatively stable. However, once mining has taken place, the minerals are broken down due to exposure to oxygen and water. Mercury as a pollutant in artisan mining is due mainly to gold processing, when mercury is used to amalgamate gold (Au). Cadmium, which is another common toxic metal, occupying position seven in the priority list of hazardous substances (36), generally occurs as an isometric trace element in sphalerite.

For centuries, mercury (Hg) has been used in the amalgamation of Au. It is estimated that about 1.32 kg of Hg is lost for every 1 kg of Au produced (37). About 40% of this loss occurs during the initial concentration and amalgamation stage of Au. The lost Hg is released directly into the soil, streams and rivers, initially as inorganic Hg, which later converts into organic Hg. This is taken up into the food chain, mainly by fish and other aquatic life. The remaining 60% Hg is released directly into the air when the Hg–Au amalgam is heated during the purification process and is often inhaled. Mercury is a very volatile element, thus dangerous levels are readily obtained in air. Safety standards require that Hg vapour should not exceed  $0.1 \text{ mgm}^{-3}$  in air. Harada (38) reported that  $200 \text{ mg L}^{-1}$  of Hg in blood and  $50 \text{ mg g}^{-1}$  in hair are the provisionally established standards and anyone with higher concentrations is considered to be at risk of poisoning.

## Metals and complex mixture toxicology

Many of the environmental issues in industrial countries are of little concern to developing nations, where morbidity from infectious diseases is high and programs for economic development to provide a minimum quality of life are the first priority (39). Therefore, health policies are most often designed to have immediate impact, and they usually and rightly concentrate on the control of communicable diseases (39, 40).

In view of this, the appearance of hazardous sites in less developed nations because of the lack of waste management programs is understandable (40-43). These sites are evidently becoming an important source of complex mixtures (43). However, industrial areas, small-scale enterprises, the production and use of pesticides, mining activities, and even atmospheric pollution are other important sources of toxic mixtures (42-46).

Since in reality the exposure to these metals (arsenic, lead, cadmium, mercury, antimony, chromium and manganese) and even fluoride do not occur singly, poisoning is expectedly to be in a cocktail fashion. It is important therefore to study the toxicological interactions between them. For example, it has been shown that cadmium increases the toxicity of arsenic in rats (47, 48), whereas in mice, the mixture of arsenic and lead provoked a 38% decrease of nor-epinephrine in the hippocampus and a 90% increase of serotonin in the frontal cortex (49). These types of studies are important for the risk assessment of metal mixtures in human populations.

## Demographics and public health of artisanal smallscale mining

Haphazard mining has led to health effects ranging from respiratory problems to mental disorders. Studies revealed that symptoms of heavy metal poisoning such as sensory disturbance, hyporeflexia, tremor, gingivitis, metallic taste, neuroasthenia and night blindness are common (37). Only recently lead poisoning was reported in five communities in Zamfara State, Nigeria leading to death of several people and animals within three months. The human victims were mostly children and women involved in artisanal gold mining. Also a cluster of unexplained illness in children <6 yrs in suburb of Dakar with a record of 18 deaths, with features including bloody vomiting and diarrhoea, irritability, convulsions and coma have been reported (50). In this out break, common infectious diseases were ruled out and chemical cause was thus suspected. It was again found to be lead poisoning due to artisanal gold mining in Senegal.

An important source of direct human exposure to high levels of Hg in Africa is artisanal gold mining and processing. Hg exposures from artisanal gold mining are mostly to the vaporized metallic form (51).

According to a study of the process among artisanal gold miners in Tanzania and Zimbabwe, up to 1.46 g of Hg is lost to the environment per gram of recovered gold, and 70-80% of these releases are to the atmosphere (52). The release of Hg during processing occurs within the breathing zone of the worker, who is typically not equipped with Personal Protective Equipment (PPE). Individuals in close contact with workers, such as children under the care of mothers who work as processors, are also at risk of exposure. Dermal exposure may also occur from contact with Hg-contaminated mining waste or during amalgam handling.

Exposure to Hg in artisanal mining is a particularly important public health issue because of the demographics of the industry: Women and children are engaged in gold mining, and their involvement spans all possible activities, including those associated with the highest risks of Hg exposure. In the Kedougou region of Senegal, the involvement of women and children ranges

from ore extraction to burning amalgam, and in the Tenkoto region, the process of amalgamation is carried out by women, within the vicinity of their young children (51). In Gaoua, Burkina Faso, the mining and sale of gold have traditionally been a female-only activity (53). According to Hentschel *et al.* (53) the proportion of the African artisanal workforce composed of women and children can range from approximately 5% in South Africa (ca. 500) to 50% in Mali (> 100,000). They also estimate that > 3000 children are directly employed in artisanal mining in Tanzania. Children engaged in artisanal mining cut across a wide range of ages. In a 1998 survey summarized by Gueye (54), about 59% of 500 children working at artisanal mining sites in Burkina Faso were  $\leq 12$  years of age.

Children are vulnerable to the toxic effects of Hg, particularly during the earliest stages of neurodevelopment. The neurotoxic effects of Hg during development are well documented for methylmercury (MeHg) and discussed extensively elsewhere (55). Despite the relative paucity of data on the effects of metallic Hg on children, similarities with MeHg in ways that predict toxicity suggest that the same target systems may be affected. For example, absorption of inhaled metallic Hg in blood is very high, and 70-80% is retained; its *in vivo* distribution is similar to that of organic Hg; and it is readily transferred through the placenta and blood-brain barrier because of its lipophilicity (56).

Data on Hg exposures among African artisanal miners are not much. However, some studies provide insight into the extent of exposure among these miners relative to the non-miners in their communities. Overall, these studies demonstrate elevated body burdens of Hg in exposed populations such as miners, workers involved in ore processing, and even children residing in mining communities. In one study of gold miners in Kadoma, Zimbabwe, the highest Hg exposures occurred in amalgam burners relative to other workers (57). Median blood Hg concentration among study participants was 5.62 ppb; the equivalent blood Hg concentration for the U.S. Environmental Protection Agency's (EPA) current reference dose for MeHg exposure is 5.8 ppb. Further analysis of the Kadoma study participants identified elemental Hg as the primary form to which the study group was exposed (57). A similar study of an artisanal mining community in Gyapa, Ghana, showed a median blood Hg concentration of 10.4 ppb and a maximum concentration of 44.8 ppb (58).

## Recommendations

It is necessary that on-site training of miners in protective measures be conducted to reduce the effects of mining on human health. The importance of dust masks, air filters and chemical gloves should be emphasized. This protective gear should be given to the miners. Miners should be encouraged to purchase such protective gear, and to continue using them for the sake of their health.

Notwithstanding this, concerted effort is still required in order to improve the health standards of the mining community in sub-Saharan Africa. Measures to be taken may include:

- (i) providing technical and professional assistance for artisan miners so as to improve their skills in mining and processing;
- (ii) encouraging the use of protective gear at all times during mining and processing;
- (iii) formation of strong mining committees with the task of planning and managing mine sites and working hand in hand with the Government authorities on health and pollution control, for example, on protection of water sources;
- (iv) strict observation of sanitation within the mines, including provision of pit latrines, boiled water, and hot meals (59).

## Mycotoxins and public health in sub-Saharan Africa

Mycotoxins are toxic secondary metabolites produced by fungi that contaminate various agricultural commodities either before harvest or under post-harvest conditions. Tropical conditions such as high temperatures and moisture, monsoons, unseasonal rains during harvest and flash floods lead to fungal proliferation and production of mycotoxins (60). Poor harvesting practices, improper storage and less than optimal conditions during transportation, marketing and processing can also contribute to fungal growth and increase the risk of mycotoxin production. These climatic conditions as well as the food production chains are characteristic in most parts of sub-Saharan Africa. Consequently, the threat of mycotoxin contamination of foods and feeds resulting in human and livestock poisoning is real and of major concern. The largest mycotoxin-poisoning epidemic in about a decade was reported in sub-Saharan Africa (61, 62). Some mycotoxins such as aflatoxins are considered by the US Food and Drug Administration (FDA) to be unavoidable contaminants of food. The goal therefore has been to minimize contamination.

However, techniques in mycotoxin management used in developed countries cannot realistically be used in sub-Saharan Africa countries because of the characteristics of the food systems and the technological infrastructure in those countries resulting in uncontrolled mycotoxin levels in these situations. The threat is made even more palpable by the fact that, staple diets in many sub-Saharan African households are based on cereal crops such as maize, which are highly susceptible to mycotoxin contamination. The food-borne mycotoxins likely to be of greatest significance in sub-Saharan Africa countries are the fumonisins and aflatoxins (63).

There is ample evidence that the inhabitants of sub-Saharan Africa are experiencing heavy dietary exposure to food-borne mycotoxins particularly aflatoxins and fumonisins.

Epidemiological studies of human populations exposed to diets naturally contaminated with aflatoxins revealed an association between the high incidence of liver cancer in sub-Saharan Africa and elsewhere and dietary intake of aflatoxins (64). For people who are infected with hepatitis B and C, which is common in sub-Saharan Africa, aflatoxin consumption raises the risk of liver cancer by more than ten-fold compared to either exposure alone (65). In addition, preliminary evidence suggests that there may be an interaction between chronic mycotoxin exposure and malnutrition, immuno-suppression, impaired growth, and diseases such as malaria and HIV/AIDS (66, 67). In a study in Ghana, higher levels of aflatoxin B<sub>1</sub>-albumin adducts in plasma were associated with lower percentages of certain leukocyte immunophenotypes (68) while a study in Gambian children found an association between serum aflatoxin albumin levels and reduced salivary secretory IgA levels (65).

Chronic exposure to aflatoxins is associated with impaired immunity, malnutrition and liver cancer, which is the third most common cause of death from cancer in sub-Saharan Africa (69). Chronic toxicity results from long-term exposure of moderate to low aflatoxin concentrations. Symptoms of chronic poisoning include decrease in growth rate, lowered milk or egg production, and immuno-suppression. The chronic incidence of aflatoxin in diets is evident from the presence of aflatoxin M<sub>1</sub> in human breast milk in Ghana, Kenya, Nigeria, Sierra Leone, and Sudan, and in umbilical cord blood samples in Ghana, Kenya, Nigeria, and Sierra Leone (60).

Aflatoxin exposure has also been suggested as a causal or aggravating factor for kwashiorkor in sub-Saharan African children (70). There is a striking association between aflatoxin and impaired growth in children (66, 71). These adverse growth effects are strongly correlated with the change from breastfeeding to solid foods, including maize, which is widely used in ground form as the basis for porridge for weaning purposes. Whether the effects of weaning foods and associated reduced growth are a direct result of aflatoxin exposure has however, not been confirmed. Turner *et al.* (65) detected AF-alb adducts in 93% of sampled children (6-9 years) in Gambia and provided evidence that IgA in saliva may be reduced because of aflatoxin exposure.

The study confirmed that children in rural areas of Gambia are frequently exposed to high levels of aflatoxin.

## Chronic exposure to mycotoxins

Two main approaches have been used to evaluate chronic exposure to aflatoxin in humans. The first approach involves food samples. Food samples collected either from prepared meals and ingredients or from markets provide the most commonly available data. The most reliable sample source for a measure of exposure is through analysis of prepared meals, because people may sort grain and remove those kernels that are considered unfit to eat. However, market and trade samples provide information on the risk of exposure from various foods in the diet, particularly when local food processors undertake operations such as milling without any quality control.

Food contamination data are available from many developing countries (Table 1) (69). Although these data generally show that a wide range of commodities are contaminated and that a significant proportion of them are contaminated to a degree far above that allowed in the *Codex Alimentarius*, little or information is available on the mycotoxin contamination profile of many food items in many sub-Saharan Africa. This is an indication for more research.

**Table 1. Examples of contamination in market food in five Africa states**

Country and food	Aflatoxin positive samples (%)	Contamination (ppb)
<b>Gambia</b>		
Groundnut sauce	-	162.0
<b>Ghana</b>		
Peanut	12.8-31.7	positive
<b>Nigeria</b>		
Corn	45	25.0-770.0
Maize-based gruels	25	0.002-19.716
<b>Senegal</b>		
Peanut oil	85	40.0 (mean)
<b>Uganda</b>		
Maize	29	1-100
Peanut, cassava	12	>100

The second approach involves biological markers of exposure. In this approach, blood, milk, or urine samples are obtained from humans and analyzed for the presence of aflatoxin derivatives, each of which has a characteristic half-life in the body (72, 73). Recent exposure to aflatoxin is reflected in the urine as directly excreted AFM<sub>1</sub> and other detoxification products, but only a small fraction of the dose is excreted in this way. Measurements of aflatoxin and its byproducts in urine have been found to be highly variable from day to day, which reflects the wide variability in the contamination of food samples, and, for this reason, the measurement of AFM<sub>1</sub> on a single day may not be a reliable indicator of a person's chronic exposure (72-74). The aflatoxin-albumin adduct is measured in peripheral blood and has a half-life in the body of 30-60 days. Therefore, it is a measure that integrates the exposure over a longer period and hence is a more reliable indicator of a person's chronic exposure. Data relating to biological exposure (Table 2) are relatively rare, because the locations of such measurements are mainly in West Africa (69). These data show major variations in seasonal exposure (75), which reflects

the natural development of contamination in storage. These biomarker data show that, regardless of food preparation practices, the human populations of these sub-Saharan Africa countries are widely and significantly exposed to aflatoxin.

**Table 2. Biomarkers of exposure to aflatoxin in humans**

Country	Exposure rate (%)	Range or test type
Benin	99	5–1064 pg/mg*
Gambia	95	0–720 pg/mg
Guinea	90	0–385 pg/mg*
Nigeria	40-90	Lung autopsies
Sierra Leone	95-99	Aflatoxin in urine
Sudan, Zimbabwe, Ghana, Liberia, Kenya, Transkei (South Africa)	32 99	Aflatoxin in urine Liver biopsy of kwashiorkors

\* pmol aflatoxin-albumin/mg albumin.

Given that little is done to decontaminate foods in most sub-Sahara African countries, it is likely that the prevalence of chronic exposure in most countries is similar to that measured in these studies with the use of biomarkers.

The prevalence of fumonisins has been reported to be 100% or close to it in all surveillance data that have been reported on maize from different parts of sub-Sahara Africa (76).

## **Recommended suggestions on the management of environmental pollution crises in sub-Sahara Africa: call for national decontamination team**

The National Decontamination Team (NDT) is responsible for providing scientific and technical expertise to local and Ministry of Health responders tasked with cleanup operations after incidents of environmental contamination involving Chemical, Biological, or Radiological (CBR) agents. The NDT employs personnel with a wide variety of educational backgrounds and professional training including an analytical chemist; Heating, Ventilating and Air Conditioning (HVAC) and other engineers; health physicists; industrial hygienists; a medical toxicologist; toxicologists; specialists in transportation and disposal of hazardous waste; and other environmental scientists and specialists. This wide range of expertise is necessary to address the broad scope of potential agents and activities needed for appropriate remediation of environmental contamination incidents. In addition to response activities, NDT scientists participate in the training of responders in the nature of CBR agents, responder health and safety, including proper Personal Protective Equipment (PPE), environmental sampling and its phases along the timeline of a response, decontamination technologies and strategies, risk assessment, and communication.

### **Role of a toxicologist in the National Decontamination Team**

Subject matter expertise in toxicology in the NDT with the Ministry of Health is invaluable in a number of ways. One particularly relevant task is to prepare health and safety information for Ministry of Health responders to the recent incident in Zamfara. Another is to advise State

Ministry of Health and other federal and local responders on health and safety issues related to the occurrence of environmental contamination.

Knowledge of toxicology has also proven useful in providing a medical perspective on the preparation of Provisional Advisory Levels (PALs).

Finally, an interesting role for a medical toxicologist in the Ministry of Health has been to serve as a liaison between responders and researchers working to meet the informational needs of response.

The Ministry of Health functions to protect human health and the environment. It has been presented with new challenges since the issue of environmental pollution and consequent decline of life expectancy in Nigeria. The NDT should be created to help the Ministry of Health meet the challenges posed by responding to incidents involving chemical, biological, and radiological terrorism agents.

## Poisoning and call for poison centers in Africa

There are few data available which can give a true indication of the extent of poisoning in the population.

The number of published studies is far outweighed by anecdotes in the press and a few small series which are held by a number of poisons advisory agencies where they exist like in Tygerberg poisons center and the Boksburg fire brigade all in South Africa.

In a report of 4830 cases of poisoning referred to the Tygerberg poisons center in Cape Town prior to 1993, 47% related to nondrug chemicals, mainly pesticides, 37% to drugs and 16% to potentially poisonous plants and animals (77). A similar report from Zimbabwe described 42 cases of acute poisoning in children below 5 years of age over two years. In that study the four commonest groups of poisons were organophosphates (38%), paraffin (26%) and traditional medicines (14%). The mortality rate was 21% (78). In a study of Muller *et al.* (1993) on the analysis of the forensic database for Gauteng (the Johannesburg area) between 1991 and 1995, they described 2272 cases in which a positive finding other than nicotine, caffeine or alcohol had been made.

Good toxicological or forensic data from sub-Saharan African countries is sparse, one exception being the series of papers from Zimbabwe (79-81) which showed a considerable contribution from traditional remedies. There is only one series of papers describing the pattern of poisoning of inpatients in South Africa. Unpublished clinical experience in Johannesburg indicates that 44% of hospital admissions for poisoning from the black population are related to paraffin ingestion; neither is the majority of cases of poisoning with carbon monoxide recorded in this database (82).

Cases of poisoning with cyanide are still available in the mining industry in some countries in southern Africa. Cyanide poisoning is however more commonly associated ingestion of plants especially cassava *Mannihot utilisima* containing cyanogenic glycosides in Nigeria. The relatively high number of cases of arsenic poisoning is due to the wide availability of arsenicals as rodenticides.

When pharmaceuticals are implicated in Nigeria and many sub-Saharan African countries, the pattern is usually different from developed countries, with analgesics like aspirin and paracetamol predominating. These are mainly associated with accidental fatalities due to abuse rather than suicide.

Records of deaths due to analgesic poisonings are poorly documented in many sub-Saharan African countries. However in South Africa deaths due to paracetamol alone and other over-the-counter drugs are quite significant, especially where the combination of paracetamol with propoxyphene was involved, which suggests that the warnings given concerning this

combination in the UK have yet to be heeded by the public in South Africa. This discrepancy may be because there are a large number of deaths in South Africa due to hepatocellular damage from a variety of causes, not all of which are investigated for toxins.

The high numbers of people living in informal shacks, which are heated by paraffin means that there is considerable morbidity caused by ingestion of paraffin by children (83). Most reports of child poisonings have been from Africa (84, 85). Kerosene seems also to be associated with household injuries and deaths due to burns. Child-proof containers for paraffin are now being actively promoted.

Erratic power supply in the teeming Nigerian population has left many households the option of alternative power generation. The only option has been use of generators that run on petrol most times in poorly ventilated environments and enclosures. Mortality caused by carbon monoxide poisoning has been reported daily tabloids with detailed records largely undocumented in medical journals. The role of the toxicologist here is in the monitoring of CO in patients; however, sadly, many never reach a hospital with laboratory facilities that include a CO oximeter.

Analyses for many herbal compounds involved in poisoning are not readily available. Some South African researchers have been working towards the production of a suite of methods for the most toxic compounds. An alternative approach is screening. There is little TLC data available, and what there is relates to the pure compounds and plant extracts and not the pattern that would be obtained in urine (82). Screening using HPLC/LDA and GC/MS has been developed in South Africa. The TOXILAB methodology would seem to offer considerable advantages, but has not as yet been applied to the detection of traditional remedies in urine in patients from a non-Western setting.

Whereas the record of fatal cases of poisonings referred to few African Forensic Science service may be documented like South Africa (82), such information may not be immediately available in sub-Saharan African countries including Nigeria. In the event of poisoning ranging from drug to non-drug poisonings to clinical toxicology or envenomations by snakes, scorpions and spiders, standardized detection, diagnosis and management modalities are lacking. Physicians more often resort to symptomatic and supportive cares with sub-optimal outcomes. The establishment of Poison Information Centres in nations of sub-Saharan Africa will solve this problem. Again it is important to emphasise the teaching of poison management in our medical and pharmacy curriculum in sub-Saharan Africa.

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# **SUSTAINABLE FOOD SAFETY AND TRANS-GENERATIONAL HEALTH OUTCOMES IN DEVELOPING ECONOMIES**

Chiara Frazzoli, Stefano Lorenzetti, Alberto Mantovani

*Department of Veterinary Public Health and Food Safety, Istituto Superiore di Sanità, Rome, Italy*

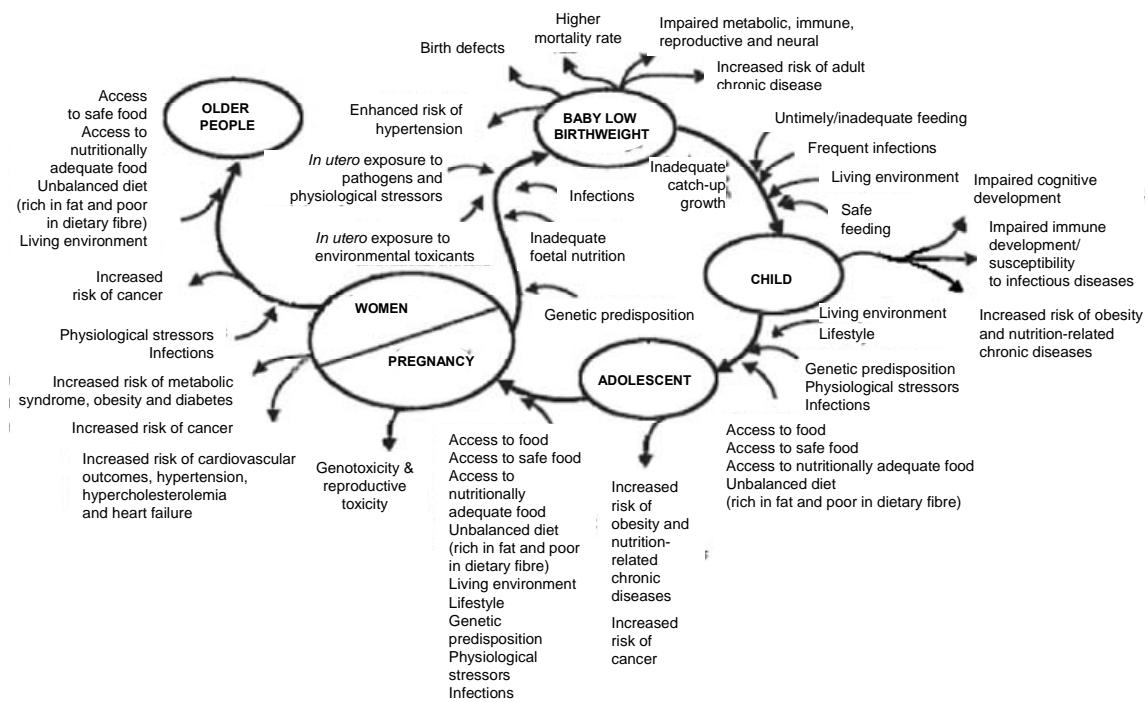
## **“Health sustainability”: the transgenerational aspect of food safety**

Food safety is a framework integrating the assessment, management and communication in relation to factors “from farm to fork” (1), i.e., from the welfare of the living organisms used for food production and the quality of their living environment, through to production, storage, distribution, processing and consumption of foods. Assessment of chronic and long-term risks deriving from chemical contamination and/or nutritional imbalances is a major component of the new food safety paradigm as implemented by International bodies, such as the European Food Safety Authority (EFSA, <http://www.efsa.europa.eu/>): special attention is given to the identification of hazards and risk characterization in vulnerable groups, including susceptible life stages. Developing organisms are highly susceptible to toxicant groups with specific modes of action such as Endocrine Disrupting Chemicals (EDCs) (2); this may old true especially when the organism’s life is dependent from the maternal organism, as in the embryonic, foetal and neonatal periods (2). Exposure to EDCs features prominently amongst chemical risk factors of concern for pre- and post-natal development (3); multiple targets, multiple exposure pathways and increasing evidence of a relation with human diseases (mainly, but not exclusively, reproductive disorders) make up EDCs as major developmental hazards. Health effects would range from adverse pregnancy outcomes to long-term impairment of metabolic, immune, reproductive and neuro-behavioural programming, as well as to enhanced predisposition to cancer: whereas accurate estimates are quite difficult to perform, it has been proposed that environmental risk factors in early life may overall account for one sixth of the global disease burden (3). Children and adolescents are also a susceptible population group, for example, to chemicals altering puberty (5). These age groups may also have different and/or higher intakes of foods as compared to the adult population, thus deserving a special attention as vulnerable consumer groups: however, the focus of this chapter is essentially the transgenerational risks resulting from dietary exposures of the mother-child dyad.

In spite of the potency of the UN statement on “sustainable development”, the irreversible damage to the natural capital in the long term did not include the “health”. The novel concept of Sustainable Food Safety “from farm to fork to womb” prompts to science-based interventions to mitigate the risks for the generation(s) to come; accordingly, target groups for intervention are not only pregnant and breastfeeding women, but also women planning pregnancy and all women in childbearing age (3). Whereas food chain sustainability is a current issue, so far the health sustainability concept has not been applied in the field of food safety.

In developing countries, such as those of sub-Saharan Africa, food safety features prominently to guarantee and promote health and wellbeing of populations, and especially of such vulnerable groups as the unborn and the child. Readily recognized environmental factors, such as poor food and water hygiene, play a major role, whereas the role of toxicant exposures

is still awaiting a proper assessment; however, available information offers ground to concern, e.g., the mother-newborn transfer of dioxins and other fat-soluble pollutants through breast milk in areas of e-waste disposal and/or recycling (6). Most important, there is a paucity of information on the impact of early risk factors, such as low birth weight, on adult health in the developing world scenarios. Notwithstanding the need for more and deeper knowledge, all evidence supports that improved access to and affordability of safe and nutritionally adequate food are major determinants to secure the health of next generations. The diagram in Figure 1, albeit not exhaustive, aims at highlighting the role of prevention in public health by showing how the poor health burden from maternal and environmental interactive effects can perpetuate through the life cycle and across generations.



**Figure 1. Progeny health includes pre-, peri- and post-natal development as well as ability to lead a healthy adulthood**

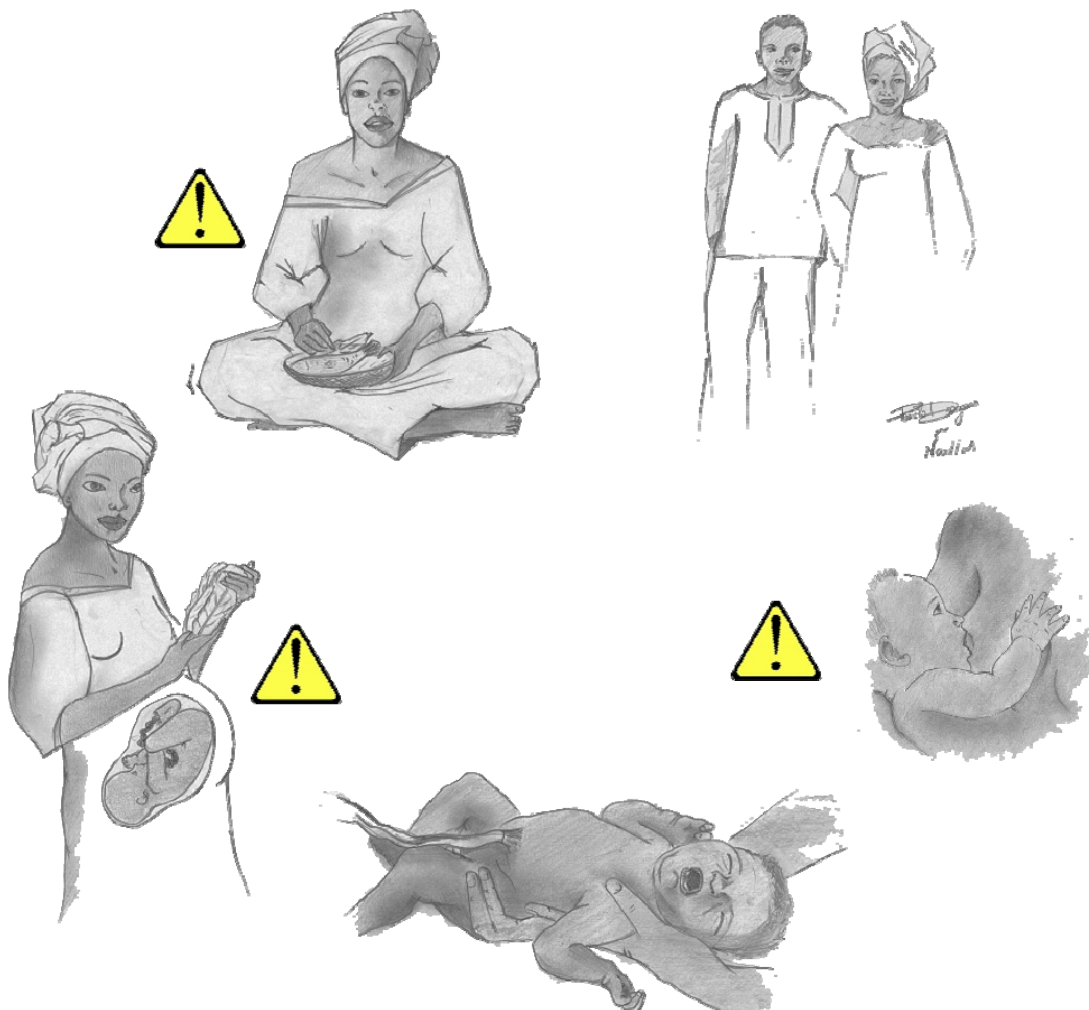
Thus, the Millennium Development Goals of reducing child mortality and increasing average healthy life expectancy within 2015 need the contribution of a comprehensive food safety framework, including adequate and balanced intake of nutrients (nutrition security).

Thus, a key issue is the definition of food safety (prevention) indexes in context still considered (often improperly) of food security (management of emergency). One example is the diffusion of food supplements as an efficient and relatively easy tool to counteract deficiencies of trace elements: however, these actions may, in some scenarios, impair the chance of empowerment of local economy. Improved quality of local raw foods, implementation of good practices by food producers and strengthened food sovereignty should actually support and integrate food safety and nutrition security. What the criterion for timely adoption of food safety policies? The question is “Prevention: when?”

## Diet of women in fertile age and poor health of the progeny during childhood and adulthood

The current paradigm for toxicological risk assessment still lies mostly in the “hazard × exposure” scheme: as Paracelsus stated, indeed some century ago, “dose makes the poison”.

A new and more complex paradigm based on the “hazard × exposure × susceptibility” scheme is recognized by the scientific community, but still awaits full implementation in the risk assessment framework. Together with gender, life stage is a main factor modulating susceptibility to pollutants (Figure 2); so, one could envisage to extend Paracelsus paradigm as “both amount *and timing* of exposure make the poison”.



**Figure 2. Life cycle phases of particular importance in the management of sustainable food safety: diet of women of fertile age, in utero life and breastfeeding.  
(drawings by Pamela Dragone for NOODLES © 2009)**

Susceptibility is not only linked to age, sex, and genetic but also to nutrition and social and economic status. Conversely, empowering the primary health care potential of people, and especially of women at childbearing age, may result an impressively cost-effective tool for health promotion. Striking examples are, respectively, the increased rates of birth defects in deprived areas (7) and the high reduction of severe neonatal morbidity through improved maternal care, including exclusive breastfeeding (8). Several macronutrients (proteins, lipids) and micronutrients (vitamins such as Vitamin A and folates, trace elements such as iodine) are especially important during development; therefore, maternal die, both before and during pregnancy, is critical to prevent an inadequate and/or unbalanced embryonic nutrition, which may also lead to long-term risk of increased burden of diseases in adulthood (see also the chapter *Transgenerational burden of endocrine disrupting chemicals: a rising global problem*).

Breastfeeding is another important issue within the Sustainable Food Safety framework. Early and exclusive breastfeeding for 6 months for all children improves the infant resistance to diseases and especially reduces infant deaths caused by diarrhoea, asthma and pneumonia (8); furthermore, it provides the appropriate nutrient requirements for the infant's development and growth. In some African countries, early and exclusive breastfeeding needs being promoted, where, for example, feeding water still is a common practice and neonates are not regularly fed colostrum. Moreover, communication and advertising on breast milk substitutes should be surveyed and regulated in health system and shopping/market settings, as well as the media, to meet compliance with the International Code of Marketing of Breast milk Substitutes.

Besides nutrients, several environmental and dietary toxicants may cross the placenta and/or accumulate in the adipose tissue of the mother with successive transfer to breast milk; in its turn, an adequate and balanced intake of nutrients may mitigate the susceptibility to toxicants (9).

Infectious diseases represent a major burden of early mortality in Developing countries. However, infectious agents do not work alone. Beyond the infectious agent itself, other factors are required to support the onset of an infectious disease, and/or to facilitate its progression or to weaken the effectiveness of immune responses. Intrauterine nutrition and breastfeeding are critical for the immune system programming; in addition some data point to the ability of widespread contaminants to jeopardize the effectiveness of antiviral defences. For instance, inorganic arsenic, a toxic trace element identified as EDC, affects the immune response to infection from the swine flu virus H<sub>1</sub>N<sub>1</sub> in the mouse (10). In humans, altered immune cell counts and enhanced risks of respiratory infections were observed in infants with increased pre- and postnatal exposure to dioxin-like compounds (11). In adults of developing countries, complex interactions among hepatitis B and hepatitis C viruses, chronic alcohol intake and aflatoxins have a strong enhancing effect on hepatocellular carcinoma risk (12). Even though much more data are needed, the available evidence suggest, that prevention of developmental exposures to toxicants may support also basal immunity and prevention of infectious diseases.

## **One example: developmental exposures and metabolic syndrome**

Malnutrition and micronutrient deficiencies are still not eradicate, even in world areas where food scarcity problems have been solved; in the meanwhile, there is a global increase of a group of severe diseases related to an excessive and unbalanced consumption of foods and calories such as obesity, hypertension, diabetes, hypercholesterolemia and cardiovascular disorders, broadly grouped as “metabolic syndrome”.

The rising epidemic of obesity and diabetes in fast developing Nigeria makes the “developmental origins” hypothesis plausible for the Nigerian population, children and



adolescents included (see also the chapter *Transgenerational burden of endocrine disrupting chemicals: a rising global problem*).

The metabolic syndrome recognizes a group of established risk factors in adult life, including the hyper-caloric/nutritionally poor diet and sedentary life, as well as, at community level, the rapid adoption of new, “urban” lifestyles and habits (3). However, the role of “developmental obesogens” must not be overlooked: the risk of developing metabolic disorders in adult life is also much influenced by additional (environmental and dietary) factors that operate during pre- and early postnatal development as “triggers”. The ‘developmental programming’ is a process during which a wrong or inadequate nutritional stimulus *in utero* or in the early neonatal life stages may establish a permanent response leading to enhanced risk of developing adulthood disease. The ‘Thrifty Phenotype’ hypothesis explains the role of insufficient *in utero* nutrition as strong programming stimulus in later development of Type 2 diabetes. The ‘Predictive Adaptive Response’ hypothesis proposes that the degree of mismatch between the pre- and post-natal environments is a key determinant in abnormal programming and subsequent disease outcome (13). Thus, the risk can remain “hidden” or further increased and triggered to elicit disease later on, depending on the safety, quality of diet and living environment, involving factors such as poor intake of non-essential but beneficial food components (e.g. antioxidant in fruits and vegetables) and enhanced exposure to undesirable compounds (mycotoxins, heavy metals, pesticides, man-made contaminants). The pre-natal exposure to EDCs can impinge on developmental programming. Mice exposed *in utero* to di-(2-ethylhexyl) phthalate (DEHP), a plasticizer and widespread environmental contaminant, altered glycogen and lipid metabolism in liver, namely eliciting a post-natal delay in glycogen accumulation and a concomitant hepatosteatosis (14). This EDC-induced phenotype is close to that in rodents with intrauterine growth retardation, which is an early risk factor of metabolic syndrome (15). Factors, including toxicants, altering IGF2-signalling pathway during the pre-natal life influence the length of pregnancy, the success of delivery as the capability of the adult liver to establish a correct glycogen accumulation (14, 15). Other widespread EDCs (dioxins and dioxin-like compounds, arsenic, bisphenol A, organotins, etc.) may alter programming of body composition by acting, for example, on the neuroendocrine glucocorticoid and/or thyroid axis (16), by altering placental function and/or by modulating epigenetic regulation of gene expression. The latter is an emerging mechanism that would definitely deserve more attention. The antiandrogenic fungicide vinclozolin has been the first EDC showing a potent transgenerational effect in rodents: altered transcriptome and enhanced risk of adult disease were observed in prostate over three generations (17). Also the long-term developmental effects on neuronal, reproductive and immune systems by the plasticizer bisphenol A have been attributed to altered epigenetic programming.

In most situations the levels of individual contaminants are too low to affect a healthy individual; however one has to consider the possibility of additive modes of action as well as, most important, the unique vulnerability of the unborn child. Exposures take place mainly through foods containing high percentage of lipids (some kinds of fish, fatty meat, and dairy products); however, this is not a general rule, for example, exposure to arsenic occurs mainly through drinking water and grains, whereas food-contact materials are the main source of bisphenol A. In its turn, metabolic syndrome is a transgenerational risk factor, as obese and diabetic women have a higher incidence of children with birth defects (19).

The risk of metabolic syndrome is associated with poor awareness of, or impossibility to adopt, healthy lifestyles and low socio-economic status. Interestingly, the same factors seem relevant also to pollutant exposures. BPA exposure has been documented in women, either pregnant and at fertile age, in developing countries; in such cases the “westernization” of behaviors and the changes from rural to urban lifestyles may have been accompanied by the

dumping in developing countries of products no more allowed in the industrialized world (20, 21). Pregnant women from low socio-economic backgrounds tend to have higher urinary bisphenol A concentrations: working as a cashier, canned vegetables consumption, tobacco smoke exposure were factors positively associated with urinary bisphenol A (22). Waste dumping is an emerging issue due to chemicals present in components of electrical and electronic equipments (chemical elements, brominated flame retardants, and non dioxin-like polychlorinated biphenyls) and chemicals released during e-waste combustion (polycyclic aromatic hydrocarbons, polychlorinated dibenzo-*p*-dioxins and furans, and dioxin-like polychlorinated biphenyls): large quantities of e-waste end up dumped in developing countries, where second-hand materials comes mixed with broken junks and no infrastructure and protocols to safely recycle and dispose hazardous e-waste exist, nor legislation dealing specifically with e-waste flow (6). Most important, contamination from hazardous waste sites involves the surrounding areas, likely of lower socioeconomic status, and frequently leads to broader exposure of the communities through pollution of agricultural fields and the feed-food chains (23).

Thus, the prevention of long-term and transgenerational developmental effects in developing countries call for an approach of social toxicology (24), where chemical exposures are viewed in an integrated way with non-chemical factors related to diet, society and culture.

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# FOOD SECURITY AND FOOD SAFETY: HEALTH INDICATORS AND ETHICAL ISSUES

Michele Farisco (a), Carlo Petrini (b)

(a) *Pontificia Facoltà Teologica dell'Italia Meridionale, sez. S. Tommaso d'Aquino, Italy*

(b) *Unità di Bioetica, Presidenza, Istituto Superiore di Sanità, Italy*

## Introduction

A non-exhaustive list of ethical issues related to food safety and food security includes: allocation of resources, equity, justice, health policies, prevention, risk management.

These and other topics are widely discussed in literature, by scientific societies, in congresses, in a long list of documents, codes, declarations, treatises.

The World Health Organization (WHO), the Organisation for Economic Co-operation and Development (OECD), the Food and Agriculture Organization (FAO) (as well as other United Nations agencies) and many other institutions and organizations at the national, international and supranational level produced key documents on these subjects.

In the midst of this vast mosaic, in this chapter we examine just some tiles concentrating on the definition and classification of health and well being indicators, and after sketching an ethical assessment of prevention we focus on food safety as an emblematic case of health indicator.

## Health Indicators

In this paragraph we propose:

- a definition of health indicators and health equity and inequalities;
- a definition of context, structural, social and intermediary determinants of health;
- a definition of well being indicators;
- a definition of the criteria to properly choose an indicator;
- a focus on the uncertainty and the limitation of the application of indicators.

The aim is to show the potential usefulness of health indicators to assess health and health inequalities, in the perspective of health as directly linked to social, political and economic factors.

The definition of health is a problematic issue in contemporary medical theory and practice (1), and it is not possible to assess it in this paper. As a starting point we assume health as a complex dimension of human life, that is as a multifaceted reality composed by several interconnected elements (health = system), so that we can define health indicators as “succinct measures that aim to describe as much about a system [particularly health] as possible in as few points as possible. [They] help us understand a system [particularly health], compare it and improve it” (2).

Health indicators may be particularly useful in order to identify and assess the so called health inequalities, that are “differences, variations and disparities in the health achievements of individuals and groups” (3).

More specifically health inequities are commonly described through three main measures: “health disadvantages, due to differences between segments of populations or between societies; health gaps, arising from the differences between the worse-off and everyone else; and health gradients, relating to differences across the whole spectrum of the population” (4).

The International Society for Equity in Health suggests this definition of equity in health: “the absence of potentially remediable, systematic differences in one or more aspects of health status across socially, economically, demographically or geographically defined populations or subgroups” (6). Many other definitions are similar and describe health inequalities which are unfair and unjust, or stem from some kind of injustices.

In an influential paper, Whitehead included the criteria that health inequities should be avoidable (7). This criterium has been challenged on the basis that it is undesirable to link equity explicitly to avoidability as this may offer reason not to act if an inequity is deemed unavoidable (8).

Whitehead identified seven main determinants of health differentials: natural biological variation; freely chosen health damaging behaviour; early uptake of health promoting behaviour; health damaging behaviour where there is severely restricted degree of choice over lifestyle; exposure to unhealthy, stressful living and working conditions; inadequate access to essential health and other public services; health related social mobility, reflecting the tendency of ill people to move down the social scale. The first three determinants are generally accepted not to be inequities. The others four are associated with health inequalities which are unjust and avoidable.

Whitehead *et al.* (9) have proposed a comprehensive response to inequities in health, consisting of four elements, each with a number of strategies. The four elements are: establishing shared values; assessing and analysing the health divide; tackling root causes; building equitable health care systems.

Given these definitions, it is important to stress that the use of indicators in general, and health indicators in particular, may have positive or negative effects: they are potentially very useful analytical tools and they allow a very useful analytical conciseness, but the choice of what indicator to use is not value-free. Furthermore, mistrust and ambivalence towards indicators derive from the intrinsic limits of indicators, which can only point out and summarize the complex system they are designed for, that must be always considered in context. Indicators generally do not give definitive answers, but only “suggest the next best question to ask that ultimately will give the answer required” (2).

As regards context, it may be broadly assumed as including “all social and political mechanisms that generate, configure and maintain social hierarchies, including: the labour market; the educational system, political institutions and other cultural and societal values” (10). Relevant contextual factors affecting health are the welfare state and redistributive policies, while the so called “structural mechanisms” include those factors generating stratification and social class division, defining individual socioeconomic position within hierarchies of power, prestige and access to resources, such as income, education, occupation, social class, gender, race/ethnicity.

Assuming well being as a complex variable, and distinguishing between current material living conditions and quality of life on the one hand and the conditions for their sustainability on the other, a document by the OECD lists the following categories of well being indicators (11):

- *quality of life*: health status; work and life balance; education and skills; social connections; civic engagement and governance; environmental quality; personal security; subjective well being.
- *material living conditions*: income and wealth; jobs and earnings; housing.

The OECD continues stressing that generally speaking sustainability of well being over time requires preserving different types of capital: natural capital; economic capital; human capital; social capital.

More specifically, as showed by the OECD (12), it is possible to summarize the following health status indicators:

- premature mortality, Potential Years of Life Lost (PYLL) and adjusted PYLL;
- infant, neonatal and perinatal mortality rates;
- life expectancy;
- health-adjusted life expectancy;
- Disability Adjusted and Disability Free Life Expectancy (DALE and DFLE).

Other health outcome indicators are:

- “sick leaves”;
- avoidable deaths;
- disease-based indicators from the Health Care Quality Indicators (HCQI) project.

Measures of health income may be:

- lifestyle factors, particularly tobacco consumption, alcohol consumption, diet, obesity;
- socio-economic factors, such as pollution, education, economic, social and cultural status;
- health care resources, such as spending on health care, human resources;
- gender and age dimensions.

As showed by *The good indicators guide* of National Health Service (2), in order to properly choose an indicator it is important to check if it regards important and scientifically valid questions, if it is valid (i.e. if it really measures what it is designed for), its possibility (i.e. if it can be associated with significant data), its meaning (i.e. what it really says), its implications (i.e. what to do starting from the indicator).

As regards the specific issue of health, it is essential to rightly choose the indicator, particularly taking into account the complex nature of health, especially its social determinants. Regarding the social determinants of health in 2005 the WHO established the Commission on Social Determinants of Health, within which the network Priority Health Conditions Knowledge Network operates.

The aim of the Commission is to clarify the underlying factors conditioning health and to define the best strategy to improve it. More specifically its goals are “brokering a wider understanding and acceptance of the social determinants of health (SDH) strategies among decision-makers and stakeholders, particularly in developing countries; translating scientific knowledge into pragmatic policy agendas adapted to countries’ levels of economic development; identifying successful interventions and showing how they can be scaled up; and ensuring that social determinants are lastingly anchored in health policy approaches at WHO and among other global actors” (13).

As regards social determinants of health, among documents produced by the Commission particularly relevant is the one titled *Closing the gap in a generation: health equity through action on the social determinants of health* (14). Furthermore the issue has been assessed by the WHO especially in the resolution *WHA62.14. Reducing health inequities through action on the determinants of health* during the 62<sup>nd</sup> World Health Assembly of the WHO (18-22 May 2009), while the central role of health equity has been affirmed by the WHO also in the paper *Primary health care: now more than ever* of 2008 (15). The relevance and complexity of the issue are expressed also by the *World Conference on Social Determinants of Health* organized by the WHO from 19 to 21 October 2011 in Rio de Janeiro.

The improvement of health conditions assessing their social determinants plays a central role even among the Millennium Development Goals (MDGs) (16, 17), adopted by 189 countries at

the United Nations Millennium Summit in 2000, with ambitious targets in poverty and hunger reduction, education, women's empowerment, child health, maternal health, epidemic diseases control, environmental protection and the development of a fair global trading system, to be reached by 2015 (12).

Clearly suggesting a social assessment of health indicators, the aforementioned Commission on Social Determinants of Health states that structural determinants and ordinary life conditions constitute the social determinants of health and consequently play a central role in order to understand health inequalities: "these (social determinants of health) include distribution of power, income, goods and services, globally and nationally, as well as the immediate, visible circumstances of people lives, such as their access to health care, schools and education; their conditions of work and leisure; their homes, communities, and rural or urban settings; and their chances of leading a flourishing life" (4).

Obviously a certain degree of uncertainty about the impact of social and economic factors on health persists: their relationship with health is not deterministic. Owing to these uncertainty and the different interpretations, the international political guidelines are quite limited. For this reason the Priority Public Health Conditions Knowledge Network defined evidence-based guidelines inspired to some key values: "a commitment to the value of equity; identifying and addressing gradients and gaps; focusing on causes, determinants and outcomes; and understanding social structure and dynamics" (4).

In conclusion we can affirm that the origin of health inequalities is the complex relationship between socio-economic, environmental and personal factors (18, 19), and the health and well being indicators are undoubtedly essential tools in order to understand health, clarify the different related problems and define the best strategy in order to improve it.

## Prevention: an ethical sketch

Generally speaking we can talk about prevention in biomedicine when the risk factors are clearly enough to quantify the relative risk (risk assessment) and put in practice adequate strategies in order to avoid negative conditions for the subjects involved (risk management).

Prevention in medical practice can be assumed according to several different meanings (20), among which two are particularly relevant.

According to a *biological model*, prevention is represented by biomedical practices aiming at the maintenance or the improvement of individual or global health or at avoiding particular diseases and/or their aggravation. According to this model prevention implies to focus on the physical and physiological dimensions of the disease trying to eliminate the risk factors connected to them. Thus in this perspective health is generally assumed as related to the physical dimension only.

Quite different is the *bio-psycho-social model*, which assumes prevention as the promotion of individual and social healthy behaviors and attitudes. This implies a wider conception of prevention strategies, aimed not only to avoid negative effects, but even to promote individual and social capabilities for a healthy life. Consequently health is not limited to the physical dimension only, but assumed in the complex perspective of the responsible human person.

From the aforementioned models two different preventive strategies emerge. From the former a healthcare model emerges, generally declined according to a medicalized and paternalistic framework; from the latter a social model is defined, particularly promoted by WHO and other international organism as well as from the so called Medical humanities.

Obviously these two fundamental models of prevention are not mutually exclusive: the first could be assumed as a basement for the second, which is a necessary enrichment of the first. If

we do not improve and promote the bio-physical conditions for an healthy life (availability of clean water, of appropriate means of care, such as gloves, gowns, masks, protective glasses, of vaccinations, of medical profilaxis, of hygiene of environment and tools, especially for cooking and caring) every attempts to a social prevention through education and information will be unsuccessful. On the other hand, a strategy only focused on the improvement of material conditions, without a cultural involvement of people, is bound to fail over time.

Particularly relevant, even for the issue of food safety, are the three “mental conditions” the bio-psycho-social model of prevention aims to promote: to perceive our vulnerability to risks; to perceive the gravity of the risks; to perceive that the risks are not totally out of our control, so that we can prevent them. In other words, prevention in medical practice reflects the complexity of health we have already talked about, and, notwithstanding the increasing urgency to switch from the strategy of reaction to that of prevention, many gaps (conceptual, policy, programmatic and funding-related) remain in this direction (21).

An ethical foundation of the priority of prevention may be inferred in the framework of public health (22). While clinical practice is characterized by a personal physician-patient relationship, public health practice implies a global attention to “collective health conditions, prevention, and social, economic, and demographic determinants of health and disease” (23).

Interest in public health is a relatively new phenomenon and it is growing on three main levels: operational, deontological and theoretical. Different ethical assessment of public health are possible: the utilitarian assessment, with the consequent possible conflict between individual and social interest; the deontological theories, according to which the good is known by its consistency with moral rules and principles; communitarian ethics, that explain morality as rooted in the historical traditions of particular communities; egalitarian theories, that promote equal access to certain goods, but not equal sharing of all possible social benefits; liberalism, which stresses equal access to rights focusing on individual freedom and autonomy; contractualist theories, according to which morally right decisions must be based on procedural justice and open processes whereby citizens are involved in deliberations; personalism, which assumes the individual as the core value and tries to achieve the common good promoting the individual good; casuistry, in which decision making takes place at the level of the particulars of the case itself.

Since professional standards for ethical practice are not well defined in public health (23), (bio)ethical and (bio)juridical discussions are necessary to mediate between different instances and to find the more appropriated way to act.

In this complex scenario, leaving aside the complex issue of the relationship between the different ethical assessments of public health, it is interesting the ethical relevance of prevention stressed by the first principle of the *Public Health Code of Ethics* proposed by Public Health Leadership Society in 2002, concerning the primary goal of public health (24): to address “the fundamental causes of disease and requirements for health, aiming to prevent adverse health outcomes”.

The essential role of prevention is outlined, for example, in the report *Preventing disease through healthy environments* by the WHO (25). Assuming the complex meaning of health sketched above, it “focuses on the environmental causes of disease and on how the different pathologies can be affected by the environment. The data show how it is actually possible to reduce the number of deaths, diseases and disabilities every year by means of a suitable environmental policy”. According to the report, “the deaths caused by environmental factors which could be otherwise prevented are more than thirteen million. In less developed countries almost 30% of deaths is due to preventable causes” (26). This means that prevention is particularly important in the case of poor countries, becoming a real political, social and ethical duty.

According to Paolo Vineis, an effective prevention implies the following principles (27): a social action; a multilevel action (education, social monitoring, etc.); ethics (it is necessary to



internalize some values); an economic and social politics; a long-term project; a changing in the conception of the causes of diseases (according to a bio-psycho-social framework); an action focused on homogeneous at risk groups; an integration of medical and educational actions.

From an ethical point of view, even if prevention is often instinctively judged a better strategy than cure in order to promote health, it is not ethically unproblematic and several issues emerge from it. Especially prevention in public health practice and programmes “systematically raise moral concerns that are different from those in ‘regular’ health care practice” (28).

More specifically, three relevant features of preventive care and public health programmes can be outlined. First of all the initiative to prevent usually comes from the public health professional, not from the “patient”. Actually, because of public health preventive programmes aim to help people to avoid disease, they are paradigmatically targeted at healthy or asymptomatic people. Consequently a possible moral issue may emerge from possible target groups to persuade to participate: how to choose them? With which criteria? For how long to involve them in the prevention strategy?

Other potential moral issues emerge from the relationship between personal autonomy and protection of individual and public health, prevention of harm and promotion of health equity. The last point is particularly problematic, and stresses another relevant difference between public health and clinical medicine: within the first interventions and prevention strategies aim to promote health at a group or population level at a reasonable cost, so that individual interest may be assumed as not a priority. In other words, we can have a conflict between private and public interests in the framework of public health prevention strategy.

Another feature of prevention is its pervasiveness, because all aspects of life may have an impact on health. This might raise ethical problems, especially if public health interventions impact upon our ability to lead an autonomous life.

These and other related issues may be assessed in the perspective of public good, assumed as not simply the aggregation of individual goods, but requiring the coordinated action of a sizeable part of the population. This kind of public good puts in question the classical liberal political doctrine requiring a broader based approach, such as consequentialism, contractarianism, communitarianism or republicanism (28).

## **Food safety and public health ethics: a few remarks**

Food safety is an emblematic case of health indicators for contemporary society. Food safety is also a very useful indicator to express the complexity of health: it is directly connected to different underlying factors, such as fragile economies, ill health, undernutrition, deep poverty, which expose the community to the effects of climate, global market conditions, epidemics and the conflicts related to the contested ownership of natural and other resources. The connection between food safety and socio-economic context is not only upstream, but also downstream of the first, so that “food-borne diseases not only significantly affect people’s health and well-being but also have economic consequences for individuals, families, communities, businesses, and countries” (29).

An historical overview of food safety assessment gives us a clear description of the increasing relevance of prevention as the most supported and effective criteria of health promoting strategies. We can identify three waves respectively focusing on hygiene, hazard and risk.

The first phase corresponds to the 1980s and “focused on hygiene and recognized the need to have good hygiene in all parts of food production, which is now considered a prerequisite in all food establishments” (29). A number of international guidelines is now available from Codex (30), part of the FAO/WHO Food Standards Programme.

The second wave corresponds to the 1990s and “focused on hazard as the element present in the food with a potential to cause disease. If this element is not removed or reduced to a level that will not cause disease, any hygienic provisions will not prevent disease” (29).

The last wave corresponds to the 2000s and focused on risk, recognizing that “the real driver for preventive efforts should be the actual human health risk recognized as human disease cases linked to specific food items. The effort would then be to move back through the food production chain to the place where prevention is most efficient or most practical” (29).

The historical development shows the progressive affirmation of a conception of health as a public and social dimension. Consequently an efficient and effective prevention strategy requires: 1) full integration of the food production chain; 2) efforts toward the real risks in the population; 3) coordination of data-gathering efforts related to food contamination and food-borne disease need; 4) realistic targets for risk reduction and the monitoring of success and failure; 5) food safety tackled both at national and international levels (29).

At this point we may ask the most appropriated definition of food safety. Technically speaking, food safety can be assumed as a scientific discipline, with two its own international journals (*Journal of Food Safety*; and *Internet Journal of Food Safety*), concerning the right way for handling, preparing and storing food in order to prevent foodborne illness. Health hazards connected to food can be transmitted from person to person or emerge from the bacteria grown in the food and causing food poisoning.

Actually safe food may have different meanings depending on the different subject involved, particularly lay people, academia, regulatory authorities and industry. Furthermore consumers are not a uniform group, differing in “age, life experiences, health, knowledge, culture, sex, political views, nutritional needs, purchasing power, media inputs, family status, occupation and education” (32). An important element still to clear is the impact of these factors on the individual conception of safe food.

Notwithstanding the aforementioned differences, some key points emerge from consumers describing the relevant aspects of safe food: “food that has been handled properly, including thorough washing of fish and poultry that will be cooked and anything to be eaten raw. Safe food means food prepared on clean and sanitized surfaces with utensils and dishes that also are cleaned and sanitized. These consumers mention the importance of hand washing by those involved in food preparation and the importance of not reusing cloths or sponges that become soiled. Common sense is a guiding principle for the educated, informed consumer” (32). Other consumers define safe food as food containing vitamins and minerals but not pesticides, or food properly stored and distributed, or food that is not contaminated.

Consumers generally assume that food safety is determined by what happens before they buy and cook the food, while published surveys suggest otherwise (33, 34). Very frequent potentially contaminant factors are quite trivial and easy to avoid causes, such as “infrequent and inadequate hand washing, inadequate cleaning of food contact surfaces, presence of pets in the kitchen, and cross-contamination between dirty and clean surfaces and food” (32).

Academic questions regarding safe food are multidimensional and involve several different scientific disciplines, such as biochemistry, microbiology, genetics, medicine, plant and animal physiology, food science and others. Furthermore the number of illnesses caused by a specific food is one of the common scientific measures of food safety.

Besides the different authorities (e.g. European Food Safety Authority in Europe and Food and Drug Administration and Food Safety and Inspection Service in USA), the WHO proposed five key principles for safe food (35):

1. Prevent contaminating food with pathogens spreading from people, pets, and pests.
2. Separate raw and cooked foods to prevent contaminating the cooked foods.

3. Cook foods for the appropriate length of time and at the appropriate temperature to kill pathogens.
4. Store food at the proper temperature.
5. Use safe water and raw materials.

The International Organization for Standardization issued the standard ISO 22000 concerning food safety with particular regard to the food chain (36). It involves interactive communication, particularly between organizations both upstream and downstream in the food chain in order to identify any hazard as soon as possible; system management; prerequisite programs; Hazard Analysis and Critical Control Point (HACCP) principles. The last point is particularly relevant, especially in the perspective of prevention, because an adequate knowing of the potential forborne hazards is essential in order to best prevent them.

The food industry “defines safe food by its specifications for raw materials and finished products. These specification define acceptable limits for chemical hazards such as pesticides and hormones, physical hazards such as bone and metal fragments, and microbiological hazards such as *Listeria monocytogenes* and *Salmonella*” (32).

Thus we can say that food safety is a composite concept emerging from the convergence of different subjects, such as consumers, special interest groups, academicians, regulatory authorities, industry. Every subject has a definition of safe food, as such simplistic because of the multifaceted nature of food safety.

A comprehensive definition has been proposed by the American Academy of Microbiology, which stated that “safe food, if properly handled at all steps of production through consumption, is reliably unlikely (i.e., the probability is low and the variability is small) to cause illness or injury” (37).

Indeed consumers have a central role in improving food safety, so that consumer education about food safety is essential. The starting point for such an education is a widely accepted definition of safe food. Furthermore food safety has economic as well as scientific implications, and it is not likely that consumers pay all the high cost of safe food: industry and government have the responsibility to improve safety and to educate consumers on the practical aspects of food safety.

It is important to take into account that at the structural level a number of social determinants (ethnicity, gender, education, migration, trade, urbanization, demographic factors and poverty) imply inequity in relation to food safety (4). Anyway the access to safe and adequate food is considered a fundamental human right by the FAO and the WHO (38). The EU has introduced the HACCP system as a necessary tool to ensure that food processing and food-related industries comply with the relevant standards (39, 40).

With particular regard to the developing countries, we think communication is especially relevant for the improving of food safety, because education gives the consumers the ability to be critically selective when choosing the food allowing good manufacturing and hygiene practices, with a key role in improving food safety standards. Of course communication, even if correct, is not enough to educate people, but education is effective only when conditions permit implementation of the recommendations and advices: “education and economic status operate synergistically. (...) Food safety communication cannot replace essential infrastructure and services. It is also important to remember that food safety education is not only a matter of knowledge transfer, but also involves fostering activities aimed at developing willingness to adopt an hygienic attitude” (4).

In conclusion we can observe that even food safety is a complex variable directly linked to several factors, especially socio-economic factors. A concept particularly useful to express such a complexity is sustainability, which entails in itself the concepts of prevention we have already talked about. Sustainable is the development which “meets the needs of the present without

compromising the ability of future generations to meet their own needs” (41). More specifically, sustainability in food production is directly linked to social and public health issues: “Sustainability of food production is clearly a key issue for societal development. Nevertheless, there is one component of sustainability that appears to deserve more consideration, i.e. the interfaces between sustainability and food safety/public health issues” (41, 42).

Of course improving food safety has different potential positive side-effects, also in indirectly linked fields such as environment and urbanization, life condition of rural producers and national economy, giving effective tools to go out of poverty. Yet there are different potential points of resistance, such as lack of resources, lack of consensus about priorities, often associated to institutional or professional rivalry, competition, institutional separation or scarce collaboration, for example between different ministers.

Health has not the same meaning for every human person in the world: it depends on social, economic, cultural and political factors. Health indicators are essential tools in order to assess health both from a theoretical and practical point of view.

Apart from these theoretical differences, every human being has the same right to healthy and safe life: more specifically, according to a capabilities approach, there is a common right to equality in the delivery of health more than equality in health achievement (43).

Food safety is emblematic: while in developed countries almost all issues concerning food safety can be generally assessed through the more or less specific standards for food preparation, in poor and developing countries the main issue is more basic and concerns the elementary condition for safe food, that is safe water and adequate hygienic standards. These are first of all political, social and economic issues, deserving both national and international assessments.

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# **TRANSGENERATIONAL BURDEN OF ENDOCRINE DISRUPTING CHEMICALS: A RISING GLOBAL PROBLEM**

Stefano Lorenzetti (a), Chinna Nneka Orish (b)

(a) *Department of Food Safety and Veterinary Public Health, Istituto Superiore di Sanità, Rome, Italy*

(b) *Faculty of Basic Medical Sciences, University of Port Harcourt, Nigeria*

## **Introduction**

In recent years, a large body of evidence pointed out how changes in the quality of the early life environment can induce, through epigenetic changes, multiple phenotypes from a single genotype. In humans, environmental constraints during development, such as poor nutrition and/or environmental exposure to Endocrine Disrupting Chemicals (EDCs), are associated with increased risk of non communicable diseases in later life, including the metabolic syndrome and cardiovascular diseases (1). In a number of animal models, the offspring of mothers given poor nutrition during pregnancy or exposed to EDCs in critical fetal or early post-natal life-stages exhibit patho-physiological changes similar to human diseases (1) with possible trans-generational effects (2). The EDC effects include several disorders of the reproductive system throughout life (abnormalities of sexual differentiation, infertility or subfertility as well as some neoplasia) and disorders of energy balance (such as obesity and metabolic syndrome) (3-7). The mechanisms are consistent with both concepts of ‘developmental origin of adult disease’ (the so-called Barker hypothesis) (8) and “developmental programming” (9, 10). They could involve cross-talk between the factors controlling reproduction and those controlling energy balance, both in the hypothalamus and peripherally. Indeed, there is now considerable evidence for non-genomic transmission of induced phenotypic traits between generations (5). Such processes may provide an important mechanism for the inheritance of disease traits in humans (6, 7). Hence, any disruption of the endocrine homeostasis can cause impairment in the physiological status of the whole organism, especially during the more susceptible developmental stages. As a matter of facts, one of the most interesting and significant feature of “developmental programming” is the evidence that adverse consequences of altered intrauterine environments can be passed from first generation to second generation offspring.

## **Environmental contaminants and the trans-generational phenotype**

To obtain the trans-generational phenotype, a negative environment is required during fetal or early neonatal life; hence, the physiologic phenotype or disease can be transmitted through the germ line even if the subsequent generations are not directly exposed to the environmental factors. The hypothesis has become well accepted by compelling animal studies that define the outcome of specific challenges such as: 1) nutrient restriction or overfeeding during pregnancy and lactation; 2) uterine blood flow restriction; 3) fetal exposure to inappropriately high levels of glucocorticoids, and 4) experimental maternal diabetes (11).

As recently discussed (11), the trans-generational phenotype, and the developmental programming as well, due to EDCs appear to rely mostly on epigenetic modifications rather than to DNA sequence mutations. Indeed, there is evidence that epigenetic changes associated with the use of EDCs (i.e. man-made chemicals) may interact with other factors that influence fetal and postnatal growth in contributing to developmental and reproductive defect as well as to cancer and to the current obesity epidemic (12).

In recent years, a particular attention has been focused on human exposure to bisphenol A (BPA), a widely used industrial plasticizer with known estrogenic properties, also due to its representativeness as “epigenomic disruptor” (13). Every year, over 6 billion pounds of BPA are used in the manufacture of epoxy resins and polycarbonate plastics, which in turn find application in a wide variety of domestic products (14). BPA is present in plastic food and water containers, baby bottles, food wraps as well as in the lining of beverage and food cans, thus presenting a large number of routes for human exposure. Numerous studies have confirmed leaching of BPA from food containers and, indeed, detectable levels of BPA are present in a wide range of packaged foods (15). Although hydrolysis of the ester bond in BPA and the resultant food contamination is facilitated by heating normal use, such as storage, brushing and dishwashing can also result in polymer degradation leading to release of BPA (15, 16). For risk assessment, a Reference Dose (RfD) – the human Acceptable Daily Intake (ADI, 50 µg/kg/day), typically 100-fold less than the No Observed Adverse Effect Level (NOAEL) – has been calculated using the Lowest Observable Adverse Effect Level (LOAEL) and 1,000-fold safety factors because a NOAEL had not been determined (17). More than 150 published studies describe BPA effects in animals exposed to <50 mg/kg/day, including altered development of the male and female reproductive tracts, organization of sexually dimorphic circuits in the hypothalamus, onset of estrus cyclicity and earlier puberty, altered body weight, altered organization of the mammary gland, and cancers of the mammary gland and prostate; > 40 of these studies examined doses less than the RfD (18).

## **Environmental contaminants and the developmental programming: beyond (epi)genetics**

As mentioned above, the trans-generational phenotype and the developmental programming due to EDCs has been associated to genetic and recently epigenetic modifications although direct effects of environmental contaminants on altered specific gene expression and/or signalling pathways affecting, among others, reproduction and development as well as altered lipid metabolism has been suggested (11, 12, 19, 20). Such phenomena are frequently reversible in adult organism but can be irreversible upon perinatal exposure apparently without the involvement of epigenetics. Among several studies performed in animal models – reviewed in Mantovani, 2006 and Latini *et al.*, 2010 (21, 22) – a couple of examples will be here mentioned selected among those ones matching the “window of susceptibility” mostly linking the developmental programming to a specific endocrine, reproductive and developmental phase, namely the prenatal exposure to environmental and dietary contaminants such as the plasticizer di-(2-ethylhexyl)phthalate (DEHP) and the  $\gamma$  isomer of hexachlorocyclohexane/HCH (lindane), a worldwide-used insecticide that although banned in most countries since many years it is still present within the environment due to its recognized persistence (21, 22).

In the first study taken as an example, DEHP has been shown to alter post-natal liver development delaying the programming of glycogen metabolism (19). CD-1 mice have been exposed by gavage to DEHP *in utero* during the period of liver development and the F1



generation has been examined post-natally at weaning and at the beginning of puberty (19). Overall, the observed results showed for the first time that DEHP can induce a long-term effect on glycogen and lipid metabolism altering the developmental programming of liver by delay of hepatocyte maturation and glycogen accumulation concomitantly to an induction of hepatosteatosis mediated by nuclear receptors.

In the second study, lindane has been shown to impact as an EDC on the female reproductive tract via a mechanism of action including the Estrogen Receptor (ER)- $\beta$  (20). CD-1 mice have been exposed by gavage to lindane approximately within the second week of gestation and the F1 generation have been examined at weaning and at full sexual maturity: the obtained results showed an increased absolute and relative uterus weight at weaning as well as an earlier vaginal patency and reduced diameters of primary oocytes at fully sexual maturity (20). Overall, without a concurrent impairment of steroid hormone metabolism, lindane elicited in F1 subtle effects on female reproductive development likely mediated by ER $\beta$ -mediated pathway(s), as direct interference of lindane on ER $\beta$  has been shown in an *in vitro* test system (20).

Last but not least, the most compelling evidence of a role of EDC in an altered developmental programming came from the testicular dysgenesis syndrome (TDS) hypothesis initially proposed by Sharpe and Skakkebaek (23, 24). The TDS hypothesis rely on several epidemiological studies that have shown how conditions like cryptorchidism, impaired spermatogenesis, hypospadias and testicular cancer can be associated as risk factors for each other. In particular, it has been hypothesized that maternal exposure to EDCs may contribute to the pathogenesis of TDS with a common origin in foetal life. Indeed, animal experiments have shown that all TDS symptoms, except testicular cancer, can be induced by foetal exposure to anti-androgenic chemicals such as plastizicers (as the above mentioned DEHP) (23). However, the cause of TDS in humans remains to be determined and the robustness of the hypothesis has been sometimes questioned (25, 26).

## **Clinical adverse outcomes at birth in developing countries: the case of Nigeria**

Evidence exists that high urinary BPA levels are positively correlated with the consumption of canned foods (27), suggesting that oral exposure is likely the primary source of human exposure to BPA. Further, a recent study found that urinary concentrations of BPA collected from male and female partners on the same day were correlated, suggesting a common source of exposure, most likely diet or common residential sources (28). Human consumption of BPA from food cans alone has been estimated to be about 6.6 mg per person per day (29, 30). Given the widespread dumping of banned baby bottles from developed nations in sub-Saharan African countries, it can be said that sub-Saharan Africa is living with an invisible poison. The work of Pouokam *et al.*, published also in this volume, perhaps the first attempt in sub-Saharan Africa to quantify the size of the dumping of BPA-containing baby bottles in Cameroon and Nigeria, is quite revealing. The baby bottles sold in Cameroon and Nigeria resulted to be mostly containing BPA, whereas the ones labeled as BPA-free were not exceeding about 27%. Since prenatal or neonatal exposure to BPA has been associated with anomalies in male reproductive function – including increased anogenital distance amongst others (31-33) – it is timely to ask the question if the currently available human data are adequate to support a conclusion that EDCs affect the anthropometry of Nigerians already at birth. In anthropometric measurements (length at birth, birth weight and anogenital distance (AGD) involving 139 newborn infants, none of whom had congenital defects or had been admitted to the neonatal intensive care unit/NICU (Table 1), it

has been observed a significant difference between the AGD values in male and female babies in such a Nigerian sub-population (34).

**Table 1. Anogenital distance (AGD) in Nigerian male and female babies**

Gender	Anogenital distance (cm, mean ± SEM)	Birth weight (kg, range)	Length at birth (cm, range)
Male (n.=80)	3.02 ± 0.14	2.4-5.9	43-58
Female (n.=59)	2.58 ± 0.11*	1.8-4.7	31-58

\*p<0.0001

The purported mechanism by which androgens increase AGD in females is by inducing “labioscrotal fusion” – in normal males fusion begins caudally and proceeds ventrally, presumably androgens in females act the same way (35). This mechanism, however, does not account for why males who are not fully androgenized would have a decreased AGD, unless AGD in males is defined as being from tip of penis to the center of the anus. A set of formal AGD measures on subjects with selected congenital endocrinopathies or birth defects could be useful in evaluating whether this outcome is uniformly responsive to gross stimuli, and may help discern details of normal embryology and the consequences of disrupting it.

Swan *et al.* (36) showed that US boys with higher prenatal exposure to several phthalates had shorter anogenital/AG index, defined as AGD/body weight. There were no associated genital anomalies in either study, or the prognostic importance of AGD or AG index is not yet established. The impact of environmental pollutants on AGD in male and female babies in Nigeria is not yet known and may form the subject of a future investigation. Given the widespread dumping of BPA in baby feeding bottles in Nigeria, it is feared that this will pose some public health concern.

Growth assessment is the single measurement that best defines the status of health and nutrition in infants and children (37). In deprived communities in the developing world, growth faltering in infants occurs in association with introduction of weaning foods at about 3-4 months of age and continues until about 3 years of age (38, 39). Linear growth retardation (LGR) or stunting in children is usually associated with impaired integrity of gut epithelium and is attributed to malnutrition and a continuous burden of chronic immunostimulation by environmental antigens (40, 41).

Overall, developmental risk factors with sufficient evidence to recommend implementation of strategies to reduce or prevent their effects on young development (42) include, besides linear growth retardation and low-birthweight, psycho-social factors (*i.e.* inadequate cognitive stimulation, maternal depressive symptoms, violence), trace elements deficiencies (*i.e.* iodine and iron), diseases (*i.e.* malaria) or exposure to environmental contaminants such as metals (*i.e.* lead, arsenic). But exposure to environmental contaminants warrant further investigation to establish a link to other developmental risk factors linked to the fetal-early postnatal life stages such as exposure to pesticides (*i.e.* organophosphates and others in a variable mixture of at least five different pesticides) and plasticizers (*i.e.* BPA and phthalates) (42-46 and Pouokam *et al.*, this volume). Indeed, both pesticides and plasticizers are recognized risk factors for developmental programming and known to affect the above mentioned anthropometric parameters: hence, the risk assessment challenge for researchers needs to establish the real exposure scenario to such environmental contaminants in developing countries.

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# FEED FOR FOOD: FEED COMPONENTS AT THE FOOD SECURITY-FOOD SAFETY INTERFACE

Alberto Mantovani

Department of Food Safety and Veterinary Public Health, Istituto Superiore di Sanità, Rome, Italy

## Introduction

The ‘farm-to-fork’ approach promoted by the European Union (1) requires the assessment and control of major components of the food production chain, with emphasis on primary production. Foods of animal origin are produced by living organisms: based on this simple truth, the availability, quality and wholesomeness of foods of animal origin are closely related to the living environment of food-producing animals, and primarily on their feedingstuffs. Accordingly, feed additives and contaminants feature prominently among the opinions delivered by the European Food Safety Authority (EFSA) (2). Feed quality obviously supports food security, by satisfying the nutritional requirements and ensuring the welfare of farm animals. Indeed, the food security issue goes beyond meeting the basic community needs for proteins, fat and energy. First, animal feedingstuffs should not subtract useful ingredients to the human diet, thus feed materials should not have any possible significant use as main human foods. Then, feeds should support nutritional security, *i.e.* foods of animal origin should provide an adequate and balanced intake of such nutrients as vitamins and trace elements. As a consequence, the role of feed ingredients, including additives and contaminants, in shaping the safety of human food has stimulated an update of the concept of zoonoses, to include health risks related to the undesirable carry-over of natural substances or xenobiotics (3).

In order to discuss the diverse implications of feedingstuffs at the food security-food safety interface, this chapter presents a few examples related to three main issues: i) safety of feed materials not employed in human diet; ii) feed components to reduce the exposure to toxic contaminants; iii) safety and efficacy of feeds enriched with nutrients.

## Safety of feed materials not employed in human diet

Feed materials that meet animal requirements and do not subtract resources to human diet deserve a lot of interest, but this should not lead to forget about safety issues, that might be related either to the intrinsic presence of undesirable substances and/or to the production process being liable to contamination.

A telling example is hemp, assessed by EFSA in 2011 (4). Hemp (*Cannabis genus*) is still an important textile worldwide: as by-products, several types of feed materials are derived, including seed, seed-derive meal/cake and oil and whole plant. Due to the high content in lipids and protein hemp materials can be useful complement of farm animal nutrition, at inclusion rates < 5%; the whole hemp plant has a high fibre content, making it suitable for ruminants at daily amounts of up to 1.5 kg (dry matter) for dairy cows. Alongside with advantages, hemp contains the potent psychotropic substance tetrahydrocannabinol (THC), which is mostly associated to the leaves. The hemp varieties allowed for cultivation in Europe need not to exceed 0.2% THC in dry matter; the average THC content detected in an European survey

(2006-2008) was 0.075%, 2.6% of the samples exceeding the maximum content. Hemp seeds are practically free of THC (maximum 0.012%). THC carry-over does occur: the parent compound and active metabolites may be distributed to the fat fraction of different tissues and edible products. The limited data available allowed to assess consumer exposure through bovine milk only; the transfer rate of oral THC to milk from dairy cows is likely 0.15%. Compared to the abundance of studies on the pharmacological effects of THC, few could be used to derive a dose-response for unwanted psychotropic effects: based on human data, a Provisional Maximum Tolerated Dose (PMTDI) of 0.0004 mg/kg<sub>bw</sub> was derived, taking into account remaining uncertainties (possible enhanced susceptibility of children and neuroendocrine effects upon exposure *in utero*). Since the PMTDI is based on acute pharmacological effects, the consumer exposure assessment considered a single high consumption of milk and/or dairy products, according to conservative values derived from the EFSA Comprehensive European Food Consumption Database (2 L milk equivalents for adults, 1.5 L for children). Exposure scenarios were built on varying intake of hemp plant derived feed material s, milk yields and maximum allowed or average THC content: in all instances, consumer exposure to THC was considerably (2- to 90-fold) above the PMTDI for adults and for small children (1-3 years). On the other hand, the same exposure calculations applied to hemp seed-derived feed materials were always below the PMTDI. Upon this assessment, that could not take into account the THC carry-over in other foods due to the lack of data, the EFSA has recommended that whole hemp plant-derived feed materials would not be used for animal nutritional purposes and to introduce a maximum THC content of 10 mg/kg to hemp seed-derived feed materials. The issue of THC exposure through milk should be viewed as a real one in many developing countries, where a large production of hemp exist and no official limits for THC are enforced: in the northern part of Pakistan 50% of buffaloes fed hemp-containing fodder showed the marker metabolite THC-COOH in their milk, and 29% of small children consuming that milk had detectable levels of THC-COOH in their urine (5).

In recent years, increasing demand for ethanol as a fuel additive and decreasing dependency on fossil fuels have resulted in a dramatic increase in the amount of grains used for ethanol production, and in a major output of distillers Dried Grains With Solubles (DDGS) as main by-product, as well as a global commodity (6). Thus, the quest for energy of developed and emerging countries has changed the use of a large fraction of cereals, such as corn and sorghum. On the other hand, cereals as biofuel may re-enter the food production chain as DDGS are envisaged to become major feed materials that might displace other energy protein sources in animal diets. Several recent studies show that various kinds of corn and sorghum DDGS can be suitable feed materials for pigs (7) and cattle (8) from the standpoint of growth and performance. However, DDGS present potential safety issues that should not be overlooked. High compositional variation is a main problem, especially in the inorganic fraction (e.g. phosphorus), mainly due to processing steps, such as the amount of condensed solubles added to distiller wet grains and the effect of fermentation yeast. Such changes may affect animal welfare and the environmental output of animal excreta (6). Mycotoxins are the main contamination problem of DDGS, also because contaminated grain not suited for animal or human consumption might be used for biofuel production; if present, mycotoxins may concentrate in DDGS about 3-fold over the original material (6). DDGS may contribute significantly to chronic, low level exposure of pigs to fumonisin B(1) (9). On the other hand, a survey on representative DDGS samples from the U.S. ethanol industry showed no significant concerns: contamination by aflatoxins, deoxynivalenol, T-2 toxin, and zearalenone was low, 10% of samples contained fumonisin levels higher than those recommended for the most sensitive species (equids and rabbits), and the containers used for export shipping of DDGS did not seem

to contribute to mycotoxin production (10). Thus, DDGS may be suitable and safe feed materials, provided that proper risk management strategies are in place.

## Feed components to reduce the exposure to toxic contaminants

Feed contaminants are a broad issue for veterinary public health: they range from undesirable feed components (4) through to contaminants related to specific steps of food production, such as storage or cross-contamination and to environmental pollutants. Management of feed contaminants relies primarily on the implementation of good practice in feed production; specific developments may include safe and effective additives supporting detoxification as well as feed sources less prone to contamination (11).

The increasing interest in mycotoxins through climate change and, especially, global marketing of feed and food ingredients has prompted attention towards methods to combat the unavoidable presence of mycotoxins in feeds. One of the strategies for reducing the exposure to mycotoxins is to decrease their bioavailability by including various mycotoxin-adsorbing agents in the compound feed, such as aluminosilicates; another strategy is the degradation of mycotoxins into non-toxic metabolites by using biotransforming agents such as bacteria/fungi or enzymes (12). The EFSA has recently evaluated the modified aluminosilicate bentonite (dioctahedral montmorillonite) as feed additive for the reduction of feed contamination by mycotoxins (13). The recommended use levels of up to 0.3% in complete feed were not considered to pose safety concerns to farm animals; at 0.5% and higher no toxicity is observed, but bentonite may interfere with the bioavailability of the essential trace element manganese and interact with coccidiostats. No hazards to consumers are foreseen; indeed bentonite has a very low toxicity and is authorised for use in human food without restriction in Europe. However, bentonite exposure of workers involved in feed mixing or handling should be kept under control, as the additive has a high dusting potential and inhalation exposure increases susceptibility to pulmonary infections in rodents. Much attention was given to the assessment of efficacy, as in such case effectiveness has a direct bearing on feed safety. *In vitro* studies showed the ability of bentonite to adsorb aflatoxins in aqueous media at different pH values and, to a lower degree, in gastric juice; *in vitro* systems are an effective screen, however they cannot completely mimic the complex situations during digestion. Two *in vivo* studies in dairy cows exposed to feed containing <5 µg/kg of Aflatoxin B1 (maximum tolerated concentration in Europe) demonstrated a significant reduction in the milk excretion of the relevant metabolite, aflatoxin M1, at recommended use levels. Thus, effective aflatoxin binding in feed was shown for dairy cows, and the conclusion was extended to all ruminants. However, no conclusion could be taken for any other animal species due to the absence of *in vivo* data. The European approach envisages that mycotoxin binding agents may be used only when mycotoxins in feeds are within the maximum tolerate levels, so to check any residual low-level, long-term pressure on animal production; otherwise, the agents must not be employed to “recover” feeds or feed materials that are unsuitable for use, taking also into account that efficacy is not always demonstrated (14). In conclusion, mycotoxin-binding agents, or other feed additives, have to be used within good animal husbandry practice and cannot replace it.

Fish farming is characterized by the primary role of feed materials of animal origins, i.e., oil and protein sources derived by aquatic organisms. This renders the production of fish liable to bioaccumulation and carry-over to human diet of persistent, lipophilic endocrine disruptors (polychlorinated biphenyls, dioxins, brominated flame retardants) and methylmercury (15). As a



consequence high levels of contaminants may somewhat reduce the recognized beneficial action of nutrients (e.g. omega-3) for which fish is a substantial source (15); contaminants might also impinge on metabolic pathways regulated by nutrients (16). The hazards from aquaculture feed contaminants are especially related to the developing lifestages: methylmercury specifically affects brain development (17), endocrine disrupters impair the hormone network regulating the programming of the organism (18). As for methylmercury, a European survey showed that in complete feedingstuffs for fish 8% of samples exceeded the maximum tolerated level of 1 mg/kg total feed. The resulting contamination levels in farmed salmonids indicate that the weekly consumption of two fish meals, as recommended by nutritionists, would not pose any appreciable health risk to consumers; however, limited data exist for other farmed fish species, that can be, nonetheless, important for consumer's intake (17). EFSA has pointed out feeds as a critical point to reduce consumers' exposure to bioaccumulating contaminants whilst maintaining the nutritional benefits of fish farming (15).

The integrated project AQUAMAX (European 6<sup>th</sup> framework programme) has been implemented to support fish farming, as a sustainable and safe source of nutrients, through an interdisciplinary effort. The primary AQUAMAX objective has been to develop feeds based on sustainable alternatives to fish meal and fish oil, producing healthy and minimally contaminated fish that are highly nutritious and acceptable to consumers; to this purpose, vegetable ingredients have been exploited in order to set novel diets with minimal contamination levels suitable for major aquaculture species (Atlantic salmon, rainbow trout, gilthead sea bream, common carp and Indian major carp). Life Cycle Assessment showed that the development of new feeds led to improvements in terms of net primary production, whilst the increased use of vegetable sources can induce an increase in land competition as well as other impacts such as eutrophication and terrestrial ecotoxicity. Moreover, AQUAMAX focussed on risk-benefit assessment for consumers' health. Health benefits of fish farmed on the new diets are assessed in an intervention trial on pregnant women at high risk for atopic disease, and their offspring, based on the possible preventive action by a good intake of long chain omega-3 fatty acids. In addition, the direct toxic effects of relevant contaminants (including brominated flame retardants, highly present in fatty fish and still insufficiently considered by feed and food monitoring programmes) are assessed together with the modulating effects of beneficial nutrients in fish farmed with traditional and novel diets; toxicology studies are performed on prepubertal rodents, as models of children considered as a vulnerable group of direct consumers, and using realistic intake levels. Finally, project's actions included also the assessment of consumer's perception of both farmed fish and fish fed with new diets. AQUAMAX has concluded in 2010, the output of publications being still on course: objectives and achievements are presented in the project's website ([www.aquamaxip.eu](http://www.aquamaxip.eu)). Ultimately, AQUAMAX shows that feed quality and wholesomeness can be fully relevant to the new conceptual framework of "sustainable food safety", covering actions to promote the health of generation(s) to come through interventions on the food chain (19).

## **Safety and efficacy of feeds enriched with nutrients**

Nutrients are often supplemented to feedingstuffs to prevent possible primary deficiencies and/or secondary deficiencies due to, for example, increased requirements by high-producing animals. Extensive research is carried out since years to enhance nutrient's bioavailability, such as the development of a number of organic compounds of essential trace elements; however, enhanced bioavailability might entrain a higher carry-over to edible tissues and products, with potential safety problems (20). Nutrients are not safe by definition: as regards nutritional feed

additives, the general approach adopted by EFSA seeks that the estimated intake from foods of animal origin plus the background intake from other dietary sources needs not to exceed the Upper tolerable intake Level (UL), as the highest level of daily intake that is likely to pose no risk of adverse health effects for almost all individuals in the general population (e.g. the seminal opinion of the Panel on Additives and Products or Substances used in Animal Feed, FEEDAP, on iodine use in feedingstuffs) (21). Thus, the real consumers' advantage from nutritional feed additives stems from guaranteeing animal welfare and production without posing risks of any excessive exposure. In some cases, the safety assessment requires a special consideration to potentially vulnerable consumers subgroups. In assessing the safety of vitamin A in animal nutrition, the FEEDAP considered that the UL (3000 µg retinol ester -RE- from preformed vitamin A) was appropriate for the general population; however, data on adverse impact bone health risk suggested a lower UL to protect elderly people, as a vulnerable population subgroup. Insufficient dose-response data did not allow to establish a new UL, but only a provisional guidance level of 1500 µg RE/day for persons at a greater risk of osteoporosis and bone fracture, particularly postmenopausal women. About half of the intake of total vitamin A in European consumers comes from carotenoids in vegetable foodstuffs of plant origin, the other half from preformed vitamin A in foods of animal origin. Only preformed vitamin A is of safety concern: liver, and to a lesser extent, milk fat and egg yolk are the significant sources. The countries of Mediterranean Europe show proportions of population exceeding the UL and the guidance value in the range of 5% and 10% respectively, while the proportion in Northern Europe are much lower ( $\leq 3\%$ ); consumption of liver, milk, including dairy products, and supplements containing vitamin A are the main determinants of high intake in the different countries. Most important, the FEEDAP Panel noted that maximum allowed concentrations of vitamin A in feeds in Europe largely exceeded the animal requirements. Thus, in order to avoid extreme values in foods of animal origin and protect vulnerable consumers while maintaining adequate levels in animal nutrition, the FEEDAP Panel recommended to reduce maximum vitamin A contents for complete feed and complementary feedingstuffs, as well as to monitor preformed vitamin A in foods of concern after introduction of revised maximum contents (22). EFSA assessments are based on exposure data relevant to Europe; thus, it might not be ruled out altogether that in a different context (age group distribution, vitamin A intake, etc.), the assessment outcome could have also been different.

Therefore, nutritional additives in feeds should meet animal requirements. However, using feeds to enrich foods animal origin is considered a worthwhile development by several industries and research groups. In 2011 the FEEDAP Panel has assessed a selenised yeast intended to improve the quality of animal product by increasing their Selenium content, hence their nutritional value; the proposed usage level was up to maximum allowed content of total selenium in feedingstuffs, 0.5 mg/kg. A certain increase of the selenium content of edible tissues and products is a characteristic consequence of Se supplementation to the diet; under this respect, the selenized yeast was markedly more effective than inorganic sources, eliciting an evident, dose-related rise in deposition. Higher bioavailability is related to composition of selenium from selenized yeast, which is 70% selenomethionine: this is incorporated into proteins, where it is interchangeable with sulfur containing methionine, as well as acting as Selenium reservoir. In its turn, higher bioavailability has a significant bearing on consumer exposure, too. A conservative exposure assessment for adults and small children (age 1-3 years), was based on food consumption values from the Comprehensive European Food Consumption Database, as in (4), and adding background intake. Estimated exposure of adults was below the UL (300 µg/day). For small children the likely total exposure after consuming milk, meat and eggs from animals treated with 0.2-0.26 and 0.3-0.35 mg/kg feed of selenium from selenized yeast, plus background intake from food of non-animal origin of 10 µg/day, was 66 and 75 µg/day, respectively: by comparison, the age-adjusted UL for children 1-3 years old is 60 µg/day. Taking into account

that i) selenium excess may cause actual health risks in humans, and ii) the inherent conservativeness of exposure assessment (based on 95<sup>th</sup> percentile consumption values of consumers only, thus excluding non-consumers from calculations), The FEEDAP Panel concluded that safety of vulnerable consumers, in this case children of 1-3 years of age, is given only at a maximum supplementation level of 0.2 mg/kg feed of Selenium from selenized yeast. The FEEDAP Panel also identified a need for specific analytical methods to detect organic compounds of essential trace elements in feed, independent from the inorganic element background (23). Based on the recent EFSA assessment, enrichment of foodstuffs with Selenium through animal feed supplementation can only be considered on a case-by-case basis, in areas with a recognized Selenium deficiency and should be integrated with a plan to monitor Selenium intake, with a special attention to vulnerable groups.

## Concluding remarks

It is worthwhile promoting research on novel feed materials and additives that can improve animal production, increase nutrient content of foods of animal origin and reduce the carbon footprint of farm animal rearing; consumer safety assessment should be considered a necessary component of such research, as safe feedingstuffs are one essential basis of food safety (1-3).

Whereas development of safer feedingstuffs requires the toxicological expertise, toxicology could also upgrade its approaches; when needed, risk assessment could address, in a comparative way, different scenarios in order to indicate the solution presenting the lowest risk. Examples are provided by EFSA opinions on hemp (4), distinguishing the safety implication of different hemp-derived feed materials, as well as on vitamin A and selenized yeast (22, 23), indicating options to safeguard both animal nutrition requirements and prevention of risks for vulnerable consumers groups. In the meanwhile, feed science and technology can provide a remarkable contribution to improved safety, by developing new ingredients less liable to contamination (AQUAMAX) or through the characterization of production processes of novel feed materials in order to set risk management strategies (6). The synergy between toxicological risk assessment and feed science and technology might even be viewed as a small-scale model of the integration between food security and food safety.

Finally, the EFSA assessments have to consider primarily European feed and food practices as well as exposure scenarios; based on analogous data, conclusions might be different in settings other than Europe. Nevertheless, EFSA assessments point out frameworking criteria that hold valid beyond Europe. Two examples are quoted as final remarks. First, safety assessment should always identify and consider possible population subgroups that may have increased exposure and/or susceptibility: as well evidenced by the endocrine disrupting contaminants, the developing organism can be a critical target of both risks and actions aimed at risk reduction, according to the “sustainable food safety” approach (19). Second, novel feed additives and technology should always be intended to support good farming practices, not to replace them; indeed, the health and welfare of food-producing living organisms is a primary element to ensure food security as well as food safety.

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## **TRADE NOT AID: CHALLENGES FOR MARKET DRIVERS OF SAFE FOODS IN AFRICA**

Chiara Frazzoli

*Department of Veterinary Public Health and Food Safety, Istituto Superiore di Sanità, Rome, Italy*

### **Chances for food safety in the perspective of the emerging African food market**

A few decades ago, few outsiders believed that India would make the economic leaps it has made. This required entrepreneurial initiative and political courage: a large part of Africa stands at a similar threshold today and its best hope is entrepreneurship and market development (1). The African continent is responsible for less than 2% of world trade but specific findings reveal why some African countries with key economic, social and political ingredients are becoming more attractive locations for foreign and domestic investments (2, 3). Africa needs trade not aid to fight poverty; building successful enterprises will build wealth by supporting political and economic stability and offering better quality goods and services to African consumers. What's the role of scientific research in this economical development?

As a first pillar, one should consider that the driver of economy is food: the power and sovereignty of Africa comes from within, from its land and primary food productions. African lands are potentially rich in crude/raw foods but often poor in management and access to the local and global market. Food insecurity grows worldwide, with the global challenge of about 925 million people currently undernourished. Developing countries account for 98% of this number, while a significant number live in sub-Saharan Africa. Feeding an additional 1.4 billion people by 2030 or a global population of 9.1 billion people by 2050 would require food production to increase by 50%. Currently, Africa registers the lowest level of agricultural productivity in the world. The world food crisis makes the investment in African food producers more crucial. Of course, serving the food market means overcoming the myriad economic, political, and social challenges facing the continent, but entrepreneurial business across Africa have already proven that this is possible and that the growth rates in Africa far outstrip those of developed markets (1).

African leaders are increasingly recognizing that they cannot afford to remain isolated from the global economy to join a growing international business movement that is developing globally and locally, between Africa and other parts of the world and between the public and the private sector (3). The Millennium Africa development plan is the first Africa-led revitalization of the continent in which the rest of the world can contribute as partners, not donors, with potential to develop, among others, agro-industry (3) and with opportunity for implementing food safety on the continent. As suggested by Mahajan (1), to support food enterprises, one needs to first look beyond Africa as a charity case to see it as one of the world's most important emerging market. The world is changing the way it looks at Africa but somewhere the general simplistic view of the African continent is still as a place of "interminable sorrow, famine, disease, and lost causes". Most African countries historically have not had the financial and technical capacity "to present their own images to the world" and change the perceptions of the continent's economic, social and political progress. If Africa begins to organize and use its knowledge of its own markets, this view will continue to change and also its population will appear as 900

million consumers: a dual new scenario – Africa as producer and Africa as consumer –, with tremendous implications for food business (1).

So, the second pillar for public research is that public health actors have pivotal role to make food safety rise along with food trade, to guarantee balancing between social development and sustainable health progress. Indeed, riding the emerging market opportunities presents a challenge for prevention: applied research in food safety and food security should be encouraged to deeply understand Africa economic rising phenomena and market opportunities offered to food producers and food companies. If properly understood, the market opportunities may offer rising chances for prevention actions as well as health promotion.

A third pillar is that even though much attention is generally devoted to rural development, increasing urbanization in developing countries makes prevention strategies timely. Countries living rapid development may encounter serious problems in urban and semiurban food productions due to new and/or insufficiently controlled chemicals introduced through rapid, unplanned and uncontrolled intensive farming, urbanization, industrialization, and dumping phenomena, and due to microbiological agents, antibiotic resistance and dietary habits. Moreover, in regions where income increases from a low level and urbanization occurs, the trade patterns and per capita demand for animal protein products (livestock and fisheries products) change rapidly. The increase of urban population means also increased dependency from external food supply, thus calling for new food enterprises and food and process controls, as well as consumers' groups requiring higher quality products. Rapid changes within the animal production in urban communities can drastically influence the control systems and the mixture of imported, processed, semi-processed and raw (fresh) foods increases complexity and centrality of primary food source quality. Food sovereignty pivots on primary production of raw foods and, for a set of different reasons, the country balance between small and large farming is critical (4). Besides, an increasing fraction of population in such high-rate urbanization countries is changing food preferences. Where economic growth is robust, diets are expected to become lower in cereals and higher in animal-derived proteins and fats. Further, changing dietary habits may lead to the demand for foodstuffs with given taste, texture or colour; in its turn, this may lead to the use of feed and food additives (e.g. flavouring or colouring agents) not related to the disease prevention or production improvement in food-producing animals and plants; also, these additives might be used to mask poor food quality. Awareness and concern towards long-term risks may give rise to further problems. These countries are called to make critical choices on prevention now. Foods firms are finding ways to make a profit while expanding into the third (lower) segment of the market by creating products priced at the lowest currency possible: here, market development starts with the product and ends with selling the price and works back to the product that can be sold for that price. For instances, many companies are selling water and other beverages in plastics bags for 5 naira (about 4 cents) in Nigeria, but it has been found that some of the sachet waters contain hazardous level of heavy metals (5).

African enterprises and their social partners have important roles to play in Africa's long-term development. Africa's trading heritage is evident in the continent's ubiquitous local markets. While a 'modern' economy developed around primary production of agricultural products is largely "export focused" and controlled by large corporations (a major legacy of the colonial era), the majority of Africans continue to live and work in the traditional subsistence agricultural economy using traditional farming methods. The number of Africans working in the micro- and small-scale enterprise sector (the informal small-scale business sector) "is about double that of those employed in the official large-scale enterprises, including the public sector" (3). By working together with micro-finance or micro-credit schemes, African microentrepreneurs are borrowing start-up capitals, and by strengthening relations with local

communities, they gain access to key markets for future growth. How owners and managers of Africa's food small and microenterprises can be convinced of the added value of adopting food safety principles? Part of the solution may lay in the words (1976) of Léopold Sédar Senghor, the former President of Senegal: "In African society, technical activities are always linked with cultural and religious activities, with art and magic, if not with the realm of the mystical" (3); this view is confirmed by research in Africa, that consistently reveals that collectivism is highly valued in African societies (7). In their turn, medium and larger enterprises are giving examples of flourishing African enterprise initiatives (1, 3). Basing on the gained experience that the expansion and influence of the Internet and satellite communications have given both the international media and global civil society new tools to investigate the social and environmental impacts of enterprises at the local level (e.g. child labour, HIV/AIDS crisis), economic development needs to encompass the precautionary approach, and for start-ups and other young African enterprises the integration of social, environmental and economic principles may provide an impetus for new business opportunities (3).

Certainly, it is time to invest in prevention; when development moves forward, the introduction of prevention measures meets increasing disadvantages due to the immediate lost in some development's benefits. It is the case of food safety. Food safety has its own keys, from the feeding of the tremendous demand for education in Africa to the acquiring of information (Africa is a continent that is data poor). But the chances of food safety drown by the economical development should also not to be neglected. Rising investments from private equity and an active diaspora are expanding investments and opportunities. Communications, banking, and other drivers are creating the infrastructure for further development. But: what about scientific research? How significant research findings may be translated in Public Health prevention strategies? How research and food safety can ride the African rising market?

The following paragraphs discuss three possible tools to consider in prevention initiatives in the emerging African food markets.

## **A common route for food safety and food security**

Sustainability of food production is clearly a key issue for societal development; nevertheless, probably due to the intrinsic delay in the acquisition of long-term views, one component of sustainability still deserves proper consideration, i.e. food safety and long-term/chronic diseases. For instance, the potential effects of combined and repeated exposure to dietary toxicants (such as the Endocrine Disrupting Chemicals, EDCs) are generally long-term and possibly triggered during intrauterine and infancy development, with crucial implications for the future health status of the community, but difficult to assess in the short time (useful the appeal to the precautionary approach) and politically unprofitable.

Whether poor or rich, people need safe food. While investigating the threshold (if it does exist: emergency intervention cannot disregard prevention, also in the long-term view) between prevention and emergency scenarios (maybe mortality under 5 years, including malformations?), the boasted conflict between food safety and food security, e.g. the insufficient availability of a staple local food due to decreased production or contamination, is unjustified: the proper management of food production chain (from the interface with the environment to distribution) can multiply yield and minimize food lost (6). The risks from long-term exposures to toxicants are enhanced by some vulnerability factors, among which poor quality and/or unbalanced nutrition features prominently. On the other hand, a diet rich in protective factors, such as antioxidants, may enhance the ability of the organism to cope with such chemicals as EDCs. When risk assessment points out the case, risk-to-benefit analysis has to be performed to meet specific questions and to address regulators, policy makers and public choices. Nutritional



security can be promoted by public health prevention strategies, from soil and crop fertilization or staple food fortification, to the promotion of healthy dietary habits and improved preparation of local foods, implying knowledge of possible nutritional deficiencies due to geomedical aspects, antinutritional factors and antagonist contaminants in foods, thus widening the field of prevention from raw materials to foods as consumed. This is crucial in ordinary conditions but also in scenarios of increased nutritional requirements: here, due to widespread severe contamination, long-term required sustainable environmental remediation and regulations could be supported by these medium-term mitigating factors. Moreover, in these scenarios body burden detoxification protocols could preserve, at least, the health chances of progenies.

Apart from raw foods and recipes' ingredients, food security in high density cities is often assured by street foods. A recent investigation made by the Noodles organization (currently under publication) has highlighted some significant points by discussing the streetfood phenomenon in different emerging areas in Asia and Africa. In countries like Vietnam, meals - also as street food- generally follow the dietary pyramid and combine raw and cooked foods. In Vietnam, as in Thailand, some hygiene practices are already adopted (and the relevant "mentality" introduced therefore) and the price of streetcooking is lower than in African countries; this means that the market has found its route to the third segment of the population, that are therefore "consumers". They can spend time around a table with friends by eating good and safe foods. This finding is quite significant. It represents the evidence of the feasibility of an integrated action of food security and food safety. In sub-Saharan Africa, the streetcooking market is often not organized and one could foresee that streetcooking will be organized and launched as business in Africa by Asians. Following this hypothesis, and considering the effective prevention standpoint only, it could be more strategic for the African context to implement prevention measures among Asian actors of streetcooking business and, along with this, implementing food safety at the academic level in Africa to build the basis for adoption and sustainability of food safety practices.

A further consideration is also pivotal when dealing with the prevention approach to streetcooking from the toxicological standpoint. The FAO (Food and Agriculture Organization) classification of streetfood as cooked, pre-prepared (at home) and mixed should be reshaped to avoid the risk of circumscribing to streetfood vendors aspects that are relevant to the general population (e.g. recipes) or the primary producers (raw foods) instead. So, from the toxicological standpoint the streetfood of interest is that implying "streetcooking", i.e. adaptation of tools, recipes, packaging and storing for the kitchen on the road.

Under the mentioned viewpoints, streetcooking in Africa is far less widespread than in Asia and, if properly analysed and managed, the issue of prevention could be faced through focused education, which – as demonstrated in Asia – is feasible.

### **Feeding aspirations to next generation's better health: key driver for safe food and implications for toxicological food safety aspects**

With the slogan "Your Future, Our Milk", Companies as Cowbell Milk have captured markets across Africa. In Nigeria, a 12-gram sachet sells for 20 naira (about 10 cents), and children pour the powder milk directly on their tongues without water, avoiding concerns about finding fresh water. African milk faces challenges from international brands, which often are considered higher quality: the local brands, like local cows, do not stand a chance against such public perception.

As industrialization and social-economic growth go on, health risks related to food insecurity and poor hygiene are reduced; in the meanwhile, concern rises on the potential long-term adverse effects of low, continuous exposure to many chemicals, and their cocktails. The health

effects produced by the exposure to environmental and dietary agents during the whole development, from pregnancy to adolescence, are still incompletely understood; however, massive science-based evidence support a role in determining disease in children and in inducing effects that may become manifest only in adult life. Sustainable food safety (SFS) is the complex of actions to “build” the healthy growth and adulthood of new generations through proper and safe nutrition *in utero* and early postnatal life. In particular, nutrition of fetuses and newborns depend on the maternal diet during both pregnancy and breastfeeding (6). The sustainability concept implies acting today with insight into long-term consequences, also by a public health standpoint; indeed, the “long-term capital” is associated to the prevention of health risk factors spreading along generations through the transgenerational diet.

The key point of sustainability is to avoid irreversible damages to natural capital in the long-term in turn for short-term benefits. In this frame one should consider the analysis made by Vijay Mahajan (1):

Significant opportunities abound today across diverse segments of the African market – from the elite shopping malls to the poorest rural village. And at the center of the African opportunity is Africa Two, some 400 million strong, a huge market waiting to happen [...]. Members of Africa Two are aspiring to a better standard of living and are upwardly mobile. They are educating their children. They are purchasing consumer products. They will be the future elite. In short, they are the future of the African market.

Simple in principle, the term “sustainable development” means meeting different objectives at the same time. It implies social progress recognising the needs of everyone, effective protection of the environment, prudent use of natural resources and waste, maintenance of high and stable levels of economic growth.

The key to promote food safety in Africa may lie in building upon ‘human relationships’ and cultural values and practices. For instance, in Africa the whole family generally eats the same meal from a common pot. “Special” recipes for young children, pregnant and/or breastfeeding mothers are not envisaged within the local eating culture; thus, the SFS approach in the African context should address widely and highly consumed ingredients of main daily traditional recipes. Moreover, in collectivist cultures, people form strong and close groups, often evolving around kinship. Positive influences of collectivism could be that group members help each other financially and group contacts are useful, both in penetrating a market and in providing support when things get tough. In this frame, food producers’ cooperatives and associations may help to shape cultural values and public opinion at the grassroots level such as traditional religious or social institutions (e.g. Islamic or Christian groups, youth clubs, women’s groups, professional groups, the media, and academic institutions). African micro- and small-scale enterprises could be encouraged to make similar forms of collective commitment, promoted and facilitated by local governments, business service providers, NGOs and bilateral and multilateral donors.

### **One health/one prevention approach: how animal feeds can affect the health of our children**

Foodborne diseases are defined by the World Health Organization (WHO) as “diseases of an infectious or toxic nature caused by, or thought to be caused by, the consumption of food or water”. The Alma Ata Declaration stated that prevention and control of zoonoses is a most important function of public health, and the field of zoonoses, classically related to infectious agents, is extended to foodborne diseases linked to the environment-to-food chains (8). According to the definition proposed by Adriano Mantovani (“Any detriment to the health and/or quality of human life deriving from relationships with (other) vertebrate or edible or

toxic invertebrate animals”), toxicologically relevant chemical exposures through foods of animal origin are foodborne zoonoses, i.e. diseases transmittable by farm animals or their products to humans, thus the ‘one prevention’ approach covers the environment-feed-food and breast milk carry-over.

Animals are higher in the food pyramid and therefore both good “tanks” of environmental hazard and bioindicators of contaminant uptake and consequences of pollution. Since animals are living organisms, consumers are often exposed to metabolites and, since humans are what they eat, humans are also what food producing animals eat. When toxicants are able to bioaccumulate, a “body burden chain” may ensue: the body burden of toxicants in foods of animal origin is transferred to human tissues along life starting from the mother’s womb. It might be inferred that minute amounts ingested via the diet would not cause, in most instances, concern in a “normal” individual. But this may not hold true for vulnerable subgroups as fetuses and newborn.

Pastures and feeds are recognised as a decisive point in the definition of the quality of both animal and human safe nutrition by the European Food Safety Authority (9, 10). Feeds are composed by several ingredients, coming from different sources; pastures (that can be treated with pesticides or exposed to environmental pollutants) are usually integrated with different kinds of concentrated feeds, including several kinds of additives. The “one prevention” approach should therefore point at the correct use of additives, use of ingredients less vulnerable to contaminations, correct feeds storage (proper use of biocides and preserving agents, prevention of micotoxins), safeguard of pastures and, before all, the detection of feed/food chains more at risk.

Moreover, nutritionally secure diet and safety of local foods are protective factors towards infectious agents. Micronutrient primary and secondary deficiencies and unbalances are often referred to as “silent hunger”: foods of animal origin can be a significant source of essential trace elements, like selenium and zinc, that are amongst nutrients most involved in the development and maintenance of healthy immune system. Infectious diseases represent a burden for the social and economic development of African nations, especially since children, adolescents and pregnant women appear more vulnerable. Remarkable differences among African areas exist concerning the incidence and severity of major infectious diseases and research has indicated an important geographical link between regions with soils deficient in specific essential trace elements and peak incidences of infections in animals as well as in humans, including HIV/AIDS and malaria. This calls for veterinary public health actions to improve animal health and resistance to diseases as well as nutritional quality of foods of animal origin.

## Using existing channels

In the implementation of prevention strategies, one should consider that people and markets in Africa are connecting in new ways: the rise of ICT (Information and Communications Technology) is changing the view of education and commerce. There are few areas of Africa that have not been reached by commerce, as demonstrated by the spread of Coca Cola and cell phones to the most rural villages. Trade companies are taking the products to the people instead of waiting for the people to come to the product: might this imply that ICT can serve prevention purposes also? If driven by proper products, this perspective view is feasible and challenging.

Other possible strategies to introduce prevention in Africa may rise from the understanding of emerging patterns in African markets. For instance, possible strategies for food safety in the streetfood sector in Africa may ride the growing Asian business in Africa. Asian traders have

penetrated into the hearth of the oldest and most holy cities; they will likely organize the informal streetfood market. Chinese, Indian, Japanese, and Korean companies have already recognised the potential of the African market: the demographics of Africa (900 million people, of which 140 million in Nigeria alone) and challenges are not so different from those they have seen the rise in their own markets and they expect the same phenomena occur in Africa.

Apart from the above considerations, the community-based African societies are still the land of the “word of mouth”. In Senegal, for instance, the Senegalese Association of Midwives (ANSFES) reaches people in all the Senegalese territory by its network of 650 midwives working in villages, town and cities. Midwives have a major role in the Senegalese communities, from those settled in cities and towns to those living in small villages, thus representing a strategic tools to spread information on the territory.

Finally, the African diaspora is one of the Africa’s most valuable natural resource and drivers of wealth. In China and India, the “reverse brain drain” played a similar role in country development. Diaspora offers resources and knowledge that is not available at home. Africans living abroad are returning home to lead and create new opportunities, with tremendous impact on the development of Africa: this is especially true when considering the Associations of women (e.g. the Italian association of Senegalese women, DEGGÒ).

The link with the territory, its history, weaknesses and strengths are obviously the primary producers and, possibly, their consortia.

### **Who can best feed the country: small or large holdings?**

The issue must also be seen in the light of growing food insecurity, as food prices seem to go up. The Oxfam report (4) focuses on the production challenge contained with the ambitious question of “Who will feed the world?”. Generally, food inflation tends to improve food production as high prices incentivise more planting. Large farms (often export oriented or foreign-owned) and commercialised agribusiness tend to respond more quickly to incentives from increased food price shifts; they have access to finance, well-established logistics and connections with the market. The traditional bias against family run smallholding and small farming in general, which are thought as uneconomical and inefficient, has made smallholders receive little policy support or subsidies in South Africa. On the other hand, the Oxfam paper shows that in Vietnam and Thailand family farming is highly productive, provides sufficient sources of income and food security for large rural populations, and stimulates other forms of rural economic activity.

According to the Oxfam report, when compared with large-scale farming, smallholder cultivation has advantages on equity grounds. Smallholders’ income is between two and ten times greater than what they could obtain from wage employment only: in Cameroon, this ratio is 3.1 for palm oil and 9.9 for sorghum. It also avoids creating gender issues. These factors are particularly important when considering that increasing migration from rural cities to urban areas increases the demand for food and decreases the supply of labour in rural areas to plough land and harvest fields. Smallholder cultivations are also more resistant to climate change, maintain biodiversity, and produce less environmental impact. With regards to safety issues, sometimes large-scale farming makes sense for crops that have short shelf lives and require good storage (e.g. against mycotoxins) and transport infrastructure so they can be dispatched quickly to overseas markets, whereas small-holdings tend to favour staple food or cash crops and might be more prone to valorize underutilized local crops and distribute them widespread on the whole territory, supporting *nutrition security* of the population.

The retail food market is pushed in pro-poor direction to ensure retaining of the small-holding character of African agriculture and help diversify crop production from staple to high

value crops by its strong supply chain ties. Thus, even large-scale farming gets favoured above investment in small-scale farming because foreign investors also invest in roads, irrigation schemes, power supply and new market connections, there is considerable margin to shield and promote the important role of small-holders in the African agricultural system, also because the success of large-holding ventures have not been as promising as initially thought (4).

## **Making safe foods the “right” product for Africa**

Reaching market in Africa means having the right product at the right price; in this scenario of development of profitable products at the affordable price to reach diffused sales channels such as rural markets, scientific research and prevention actors in public health should concur to make the profitable product also safe and healthy; in this way, prevention and market could interact for a concomitant economical development on the background given by prevention and health promotion (ethical enterprise). In this chapter reflections are given on the transfer of safety and quality criteria to enterprises in Africa, but the role of African scientific research and African public health bodies are decisive to boost veterinary public health and food safety principles and findings in food business.

For a successful transition, it is necessary to create a feeling of confidence for both entrepreneurs and consumers, as well as sufficient flow of information.

Business flourishes when addresses real human needs: virtually every company or organization declares some kind of social programme designed to address the serious challenges of its consumers and employees. In an age of rising attention to corporate social responsibility, it almost goes without saying that companies have to take an active interest in social and environmental outcomes of their business, in addition to the traditional focus on financial returns.

Sometimes the market, particularly when it is related to a health or social issue, can be organized through the synergistic effect of public and private initiatives. The key issue in this synergy is making safe and wellness foods the “right” product: and this may be possible because “every market has its own key” (1). As demonstrated by niche food markets in developed economies (e.g. organics), the desire of people at all levels to improve and/or demonstrate status and wealth, the desire to express oneself through consumption as well as the search of health, cultural roots and pleasure, is what drives consumer demand. “Aspiration” is a key driver and as it rises, Africa rises with it: “there are opportunities for premium products at the high end of the market and value-oriented products at the low end. But the high end will sometimes buy for value, and low-income consumers sometimes aspire to high-end goods” (1). For instance, in many parts of the world even fast food is aspirational: families go out to quick-serve restaurants on weekends and special occasions. Making the desirable affordable implies tremendous opportunities in using marketing communication, distribution, service, and in understanding buying habits.

For instance, a number of articles report the large number of informal restaurants not dealing with minimal hygiene requirements in Nigeria. Not surprisingly the purveyors of fast foods prefer to refer to themselves as operators of ‘quick service restaurants’): this rebranding effort is quite understandable. Like much that is modern, the concept of quick service restaurants has caught on very rapidly in Nigeria. Urbanization, the changing nature of work and the restructuring of the ethos of the extended family concept have also been critical factors. In the developed countries, critical health issues relating to fast foods have been raised in the last decade or so. Nigeria is not immune to the related health concerns such as obesity and heart diseases. Since fast foods are high in fat content, this cannot be entirely surprising. What is more poignant in Nigeria is the underdevelopment of the monitoring infrastructure that is vital

to safeguard the consumer. The QSRs must face up to food safety issues and modify their raw foods, content, inputs, preparation and preservation methods. Abroad, chains like Macdonald's have already started modifying their menus by bringing in salads and greens: pressure from scientific research, public health bodies, media, public opinion, has changed needs and demands of consumers' groups and health consciousness has also increased the demand for local foods.

Nigerians constitutes the 10% of the African population. For both the aspects of massive urbanization and population density, Nigeria presents both challenges of food safety and food security; in this context an increasing concern on the safety of streetfoods and informal restaurants is envisaged, not only from the microbiological standpoint, but also from the toxicological one. Just to mention one more example, in crowded cities, delivery is essential for business: home delivery has emerged as the most important channel for sales. Safe packaging and advertisement on proper heating of packaged food should be guaranteed as well.

On the other hand, people are often unable to afford the cost of food. In this scenario, the issue of dumping of poor quality and/or unwholesome cheap food to rapidly growing areas is of particular concern. An example that has received media attention is the massive imports of frozen chicken in Cameroon. The product was sold at a very low price in local markets in disastrous sanitary conditions, creating severe problems to local poultry breeders. The Cameroonian ACDIC (Association citoyenne de défense des intérêts citoyens) campaigns against the import of frozen chicken meat and, whereas attention has been provided to the immediate health risk associated with microbial contamination of thawed and refrozen chicken, no data exist on longer term risks such as those deriving from the use of preservatives. In Europe, following the series of food safety alarms and consumers' reactions to health, ethical and environmental concerns associated with conventional, "long-chain" food systems, the European Commission has developed the new food safety strategy "from farm to fork" (11). Differently from "long-chain" food production systems, that widen the distance between consumers and the context(s) where food is produced, short food chains, exploiting as far as possible local resources, may better support food safety as they reduce the number of critical hazard points between primary producer and final consumer. This requires an overall system of farm management and food production, from preservation of natural resources through to animal welfare, as envisaged by the new vision on organic production.

Growth is rapid in Africa, and incomes are rising: Africa has growing consumer markets, particularly in the middle of the market. Members of second segment of the market ("people who can buy") are aspiring to a better standard of living, whereas pricing is absolutely critical in the third segment of the market. On the other side, the African diaspora can create a global market for Africa products, generating opportunities for decentralized cooperation programmes, feeding a fast-growing demand for wellness.

Obviously, the conditions for success or failure of initiatives are very context-specific and contingent on a country's institutions, tenure, policy, culture, and demographic considerations. Also, complex implications of religions and other social differences should be considered when handling food safety and nutritional security issues: researchers need to understand these differences and tailor the strategies to the local daily life, but also need to realize that every society has similar needs. Surely, successful initiatives are those based on a country-led long-term vision.

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# BIOSENSORISTIC DEVICES: MONITORING AND DIAGNOSTICS IN AGRO-ZOOTECNICAL PRODUCTIONS

Roberto Dragone, Gerardo Grasso

*Institute of Nanostructured Materials, Consiglio Nazionale delle Ricerche c/o Department of Chemistry,  
'Sapienza' University of Rome, Italy*

## Introduction

The emerging environmental policies increasingly adopted globally are generally aimed at promoting the development of new methodologies, eco-friendly products/processes (*green chemistry*) and eco-sustainable agro-zootecnical production. Nowadays, however, anthropogenic pollution still remains an emergency and the continuous release of xenobiotics and agro-zootecnical residues into the “environment to food” chain makes the development of monitoring systems crucial. In fact, systems enabling the detection of contaminants in environmental compartments (*in situ*), *in continuum* and with real time outputs, represent the chance to target quickly corrective actions.

The legislation regulating food safety in Europe includes the adoption of the Hazard Analysis Critical Control Point (HACCP) system “from farm to fork” and recommends primary producers to apply self-monitoring plans (1).

The HACCP system aims at early identification of hazards by setting corrective procedures and maintaining the history at any point in the food cycle production: in this frame, *sensoristic devices* (sensors and biosensors) offer the required characteristics either in terms of analytical performance (e.g. detection limit) and capacity of providing real-time results, *in situ* detection, absence or reduced pretreatment and use of reagents, easy use, cost-effectiveness. In particular, integrated bio/chemo-sensoristic systems can be effective for monitoring particularly vulnerable points of the environment to food chain. In fact, through the “holistic-like” approach based on their specific and non-specific endpoints, they can support the assessment of situations subjected to multiple stimuli, where synergistic or additives effects, are impossible to assess altogether by conventional methods.

The patented multichannel platform BEST (2) is a technology combining batteries of bio/chemosensor probes, automatic integration of responses and identification of grids of markers. Through simultaneous collection and analyses of multiple signals, *BEST* allows a nonstop monitoring for the identification of anomalous variations of the multiparametric “fingerprint” in an environmental compartment or during agro-zootecnical productions.

## Sensoristic devices

Generally a sensor is defined as “a device which detects or measures a physical property and records, indicates, or otherwise responds to it” ([www.oxforddictionaries.com](http://www.oxforddictionaries.com)). Sensors can be classified in:

- *physical sensor*, “a device that provides information about a physical property of the system” (3);



- *chemical sensor*, “a device that transforms chemical information, ranging from the concentration of a specific sample component to total composition analysis, into an analytically useful signal” (3);
- *biosensor*, “a self-contained integrated device, which is capable of providing specific quantitative or semi-quantitative analytical information using a biological recognition element (biochemical receptor) which is retained in direct spatial contact with a transduction element” (4).

Since their first theoretical conception by Clark and Lyons in 1962 (5), idea that led to the development of the first glucose analyzer for the daily measurement of glycaemia, efforts have been made to make sensors a “more intelligent” and dynamic technology. Depending on the method of signal transduction, biosensors can also be divided into different groups (e.g. electrochemical, optical, piezoelectric). Amperometric devices, in which the signal is a change in the measured current at a fixed applied bias, are the most commonly class of biosensors, because of their construction simplicity and low cost. Although in recent years the development of optical biosensors is increasing, amperometric devices may be used in various areas of research and industry (6). The optical type may involve direct or indirect detection of the analyte through optically labeled probes and the optical transducer may detect some optical property changes (e.g. luminescence or refractive index) (7).

Recognition elements are the key component of any sensor device: they impart the selectivity to the sensor that respond to a particular analyte or group of analytes, avoiding interferences from other substances. For example, chemical sensors such as ion selective electrodes, use a membrane selective for the analyte.

In biosensors, the nature of the bioactive recognition elements allows to classify them into two main groups. Selective binding affinity biosensors utilize the selective binding between the analyte and a suitable molecular probes, like antibodies or nucleic acids, immobilized onto the surface of the transducer (electrochemical, piezoelectric, or optical) (8,9). In the field of food analysis, immunoaffinity is a widely employed method; this kind of sensors is termed immunosensors (10): the antibody-antigen interaction is characterized by high affinity and high specificity and can be used for a rapid detection of analyte in water, soil or food extracts (11). Although based on same principles of solid-phase immunoassay, immunosensors (e.g. piezoelectric and surface plasmon resonance based sensors) possess advantageous features and a number of applicative examples can be listed: from the detection of foodborn pathogens cells and their toxins, to pesticides, heavy metals, mycotoxins, etc. (12-14).

Concerning other selective binding affinity biosensors, nucleic acids can be employed as biological molecular mediator, in particular together with piezoelectric and optical transducers. One of the approaches is hybridization, that exploits the interaction between DNA fragments (used as probe) and complementary sequences to detect Genetically Modified Organisms (GMOs) (9); another approach is based on protein/nucleic acids interactions using particular molecules called aptamers (single-stranded nucleic acids with a specific three-dimensional structure) that binds directly to different target molecules (15). Aptamers have many advantages as biological molecular mediator that antibodies don't have, such as in vitro synthesis, easy modification and higher stability; these characteristics make aptamers very promising for future analytical applications, including food analysis.

At the second group belong biocatalytic sensors that use biomediator, such as enzymes in isolated form and whole cells. The sensoristic bioassay is based on the variation of an enzyme activity outside (in the case of enzymes) or within (in the case of whole cells) the cellular context. Target analyte, which determine the enzyme activity variation, may act as a substrate, inhibitor or modulator of a system of transcriptional regulation (inducible bioreporters, see below). The most commonly used biological mediators in biocatalytic sensors are enzymes

because they possess analytical features suitable for quantitative determinations, for example low detection limit (until to  $10^{-9}$  mol L<sup>-1</sup>). Quantitative measures by enzymatic biosensors used to monitor the target parameter (e.g. glycaemia, contaminant concentration) are performed in the range of linearity of the Michaelis-Menten equation curve. Amperometric tyrosinase-based biosensors are examples of employment of two of the mentioned methodologies for enzyme biocatalytic sensors (enzymatic conversion of the substrate and enzymatic activity inhibition by target substance). The first approach can be employed in food quality control (16) and the second one for toxicological applications, like detection and analysis of several pesticides, herbicide or endocrine disrupting compounds (17-20). Analyte-recycling or cofactor regenerator bi-enzyme sensors have also been used (21, 22).

About whole cell biocatalytic sensors, they can be used as marker for monitoring of environmental and food safety (23-26), employing either suspended or immobilized cells (27,28). Compared to other biosensors they are characterized by a different bioanalytical criterion: by using intact biological entities they can highlight interactions and exposure effects of different substances on functional cellular structures, thus supporting the evaluation of parameters such as bioavailability and toxicity. For example, by measuring variations of the cellular respiration (oxygen consumption) with biocatalytic sensor (29), the presence of contaminants interfering with cellular respiration (e.g. due to interaction with mitochondrial functions) can be evaluated. Especially unicellular microorganisms (bacteria, yeasts, algae) offer several useful features as biomediators for sensoristic purposes, e.g. rapid growth rate, low cost, easy maintenance and the possibility of genetic engineering. Further they can be used as alternative methods to animal testing. About the latter, the considerable progresses in genetic engineering (reporter gene systems, transformation with DNA constructs, etc.) allow the modification of proper microorganisms into bioreporters usable as efficient, stable and selective sensoristic biological components suitable for semi or quantitative analyses. This kind of biocatalytic sensors relies on the ability of bioreporters to produce a detectable signal (generally optic) or its variation in response to the presence of the target analyte(s). These bioreporters can be distinguished into two main classes: *constitutive bioreporters*, for which the general toxicity of a sample can be estimated from the inhibition of a constant measurable signal produced by living engineered cells, and *inducible bioreporters*, that use a specific DNA construct made up of an inducible promoter (activated by target analyte) fused to a suited reporter gene (e.g. lux operon or GFP). These biosensoristic devices are useful tools for tetracycline residues detection in milk (30) or other chemicals including dioxins and endocrine disrupting chemicals (31).

## **Innovative biosensors employments in agro-zootechnical production**

The increasing number of potentially harmful pollutants in the environment involves feed and food productions. This situation calls for fast and cost-effective analytical techniques for rapid management evaluations and HACCP. The HACCP approach is based on a systematic analysis of each step of food production to identify critical hazard and control points for the whole food chain quality assessment and the food safety assurance. As endorsed in the conceptual framework 'from farm-to-fork' of the European food safety strategy, the whole food production chain contributes to the human total dietary intake of mixtures of chemicals. HACCP strategies are prepared to include/consider/evaluate also hazards that are not related to acute foodborn diseases. To achieve a food safety shielding along the whole food chain and to match long-term and transgenerational food wholesomeness, a risk based management of food

processes, such as the HACCP system, should be implemented by toxicological indexes and relevant diagnostic tools, as well as possible corrective actions in established toxicological critical points (32,33). In this context, a field systematic strategy combining HACCP and risk assessment appears necessary, covering the identification/control and, where possible, the removal of the risks due to toxicants along the food chains, covering food production steps or procedures at which a toxicological hazard can be identified, prevented, eliminated or reduced.

As underlined by the Italian project ALERT (Integrated System of biosensors and sensors 'BEST' for the monitoring of wholesomeness and quality, as well as for traceability in the cow milk chain), the phase of primary production represents a major interface between environmental health and food safety; thus, actions for environmental remediation of contaminated agricultural land, soil, pastures and/or water sources provide corrective actions in the food chain preventing long-term and transgenerational health risks.

Currently, mycotoxins remain the toxic contaminants for which some hazard and critical control points are more consistently identified; strategies were developed to detect and remediate the presence of mycotoxigenic fungi as well as to inhibit mycotoxin biosynthesis during pre-harvest, harvest and post-harvest management. Possible corrective actions are proposed during primary production. In its turn, the widespread adoption of decontamination/detoxification strategies (*see*: <http://www.iss.it/inte/risc/cont.php?id=214&lang=2&tipo=29>) involving, for example, chemicals and/or irradiation would require a risk-to-benefit analysis, along the lines recently adopted, for example for the assessment of the antimicrobial resistance in relation to the use of specific antimicrobial substances in foods (34).

From an analytical point of view the starting point to improve control systems abilities linked to traceability can be the gaining of a greater level of knowledge of various feed and food matrices composition, both molecular (e.g. through metabolomics) and microbiological levels. When identified useful markers, the next step is choosing of proper analytical methods for detecting and/or monitoring possible physical, chemical and biological variations also in order to identify new toxicological indexes. For these purposes, the application of most traditional analytical techniques is in contrast to the current need of rapid, cheap and easy use and portability of methods and devices. So it takes a different approach combined with a different technology. In the latest years these needs have called attention to biosensoristic technology as more suitable instrumental methods for in situ monitoring and also for carrying out HACCP plans. Indeed features like high sample throughput and reduced or free reagent using, leading to an overall decrease of analysis costs and easing a more quickly decision-making process. Furthermore basic prerequisites of compactness, miniaturization, automatism, portability and remote control are feasible through a series of technological innovations that lend versatility to these systems to the point of exploit their full potentials; they include flow injection analysis, nanotechnology and wireless protocols. Flow injection analysis (35) and more recently variations of this technique like multisyringe flow injection analysis (36) had revolutioned the concept of samples manipulation, with advantages as automatic high sampling rate with reduced costs (37). As concerns nanomaterial science and bionanotechnology research, many new materials (e.g. carbon-based nanomaterials) suitable for both design and improving biosensoristic devices have been produced (38). Also miniaturization technologies, microsystems (MEMS or MST) and integrated circuits (particular CMOS technology) allow to design micro or nanobiosensors that integrate one or several laboratory functions on a few square centimeters sized (lab-on-a-chip) (39, 40). Finally, employments of wireless technologies allow a remote management and coordination of sensoristic platforms by both personal computers and handheld devices such as smartphones. The "Milknet" project constitutes a recent example of a sensoristic platform for telediagnosics starting from farm raw milk. This

proposal won the 2011 Second Edition of ‘Start Cup CNR - Il Sole 24 Ore’ during the Festival of Science of Genoa (41).

## **Sensoristic devices for a new approach of integrated analysis**

In the evaluation of benefit and hazard food-related parameters, traditional approaches (like quantitative analysis of a certain mixture) based on laboratory techniques, are unable to show us the real context resulting from the co-presence of several substances with similar or opposite action, whose effects is hardly theoretically predictable.

To properly evaluate the real effects of a food matrix a broader modern vision based on the concept of ‘whole food’ is taking off, both regard nutritional and toxicology characterization. In fact, the composition of a feed and food matrix is a complex composite of various constituents: this is the result of different biological processes that carry out an integrated action on individual compounds (both nutrients and contaminants).

On consumers the ‘net effect’ is necessarily different from the corresponding actions of each isolated compound; i.e. we could consider the ‘net effect’ in analogy at the ‘resultant force’ in mechanics. When considering the hazard of chemical contaminants exposure of food, it will be influenced by the co-presence of several potentially toxic substances. In addition, they can act in additive or synergistic ways, carrying out possible noxious consequences even at doses below the limit of action of each substance taken individually.

So for a better food hazards identification and characterization it’s necessary to look into the complexity of feed and food matrixes with a new vision, holistic-like. This new approach overcomes limitations of scientific measurements currently used in agro-food field, mainly focused on the independent analyses of various parameters. On the contrary integrated analyses of physical, chemical and biological parameters by sensoristic devices can be more proper for a characterization of food ‘as a whole’. Indeed, establishing correlations or cause-effect relationships amongst different data (multivariate analysis), such integrated information from multiple markers could help to identify a “fingerprint” of food matrices. As already mentioned in the introduction, the multichannel platform BEST (2) is a practical application of integrated analytical approach; this is an HACCP-like monitoring system that operate through at least 4 principles: identification, control, simultaneous and nonstop monitoring of anomalous variations during agro-zootechnical productions, developed to allow simultaneous collection and analysis of multiple signals, that constitute a flexible grid of toxicity indexes in series, for early hazards management. The system is arranged with a battery of probes (analogical and/or digital ones) appropriately selected and integrated each other, functioning simultaneously.

Therefore, ‘field laboratory’ (based on integrated analysis of multiple parameters), designed for ease of interpretation and use, cost-effectiveness, eco-compatibility, compact, portable and remote management, can constitute a model for future area of sensoristic sciences, especially for innovative employments in environmental and food fields. Within this holistic analytical approach, biosensors possess a great applicative potential and they are a powerful alternative to conventional analytical techniques for on-site screening and diagnostics in environmental and agro-food fields.

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# BIOMONITORING OF MODERN ENVIRONMENTAL HAZARDS IN AFRICA

Orish Ebere Orisakwe (a), Chinna Nneka Orish (b)

(a) *Faculty of Pharmacy, University of Port Harcourt, Nigeria*

(b) *Faculty of Basic Medical Sciences, University of Port Harcourt, Nigeria*

## Introduction

Human bio-monitoring is an important tool in environmental medicine to assess and evaluate the level of internal exposure of the general population, population groups and individuals to environmental pollutants. Bio-monitoring has been used to evaluate exposure and risks for various environmental pollutants by means of biomarkers of exposure (internal dose) and biomarkers of effects. The project of biological monitoring includes the monitoring of toxic substances (traces elements or heavy metals). Cadmium, mercury and some other heavy metals are naturally occurring metals, but most human exposure occurs as a consequence of human activities. Mounting awareness and concern about environmental pollutants and their adverse health effects have led to an increase in measures to protect the public from avoidable exposures. The level of toxic metals in human tissues may represent the important indicator of the health status. Environmental Health Impact Assessment (EHIA) through the measurement of chemicals in human tissues and fluids (human monitoring) and environmental media (ambient monitoring) may be common in many parts of the world but not in Africa.

In view of the poorly developed or neglected EHIA in sub-Saharan Africa, nobody knows or understands the impacts of unmitigated release of Modern Environmental Health Hazards (MEHs), alone or in combination with traditional hazards of poor sanitation and malnutrition, on morbidity and mortality in sub-Saharan Africa countries, except that they are guessed to be serious. As example, sub-Saharan African countries have used highly persistent pesticides such as DDT, dieldrin, endrin, heptachlor, lindane, and toxaphene, for more than 50 years for controlling disease vectors and combating agricultural pests. The way in which these pesticides are used in Africa leave room for concern about the environmental and health consequences compared to practices in other countries.

Human monitoring in sub-Saharan Africa is limited by poor infrastructures, lack of trained personnel, shortage of essential reagents and other supplies, and slow manual technologies (1). Although large amounts of data on blood lead have been reported in many parts of the world, reliable measurements in sub-Saharan Africa remain limited, and the extent of childhood lead poisoning in the continent is basically unknown. In this regard, one can call into question the recent (and not so recent) estimates of disease burdens using “guess-estimated” demographical and health surveys, statistical modeling and census information. These estimates serve to remove the pressure on national governments in sub-Saharan Africa from obtaining their own estimates and may even inhibit the capacity building required for monitoring and evaluation, with the result that there are few advocates for the type of study required to obtain reliable bio-monitoring information (1).



## Public health importance of biomonitoring in Africa

Akinloye *et al.* found higher levels of serum and seminal cadmium in azospermic males attending the fertility clinic of University College Hospital, Ibadan Nigeria. These men were un-occupationally exposed. In Nigeria this problem may be more deleterious because of the well recognized deficiency of protective micronutrients in this sub-region (2, 3).

Sosan and coworkers 2010 (4) showed that cacao farmers in Southwestern Nigeria do experience significantly reduced erythrocyte acetylcholinesterase enzyme AChE activity and hemoglobin levels following insecticide application. The occupational exposure is presumably due to the diazinon formulation that the farmers use for the control of cacao mirids. In the baseline AChE activity measurement, some of the farmers had relatively low activities, ranging from 33% N to 50% N. Any AChE activity that is lower than 50% is indicative of poisoning (5) and, hence, these farmers presumably have been chronically poisoned. They concluded that a regular biomonitoring of cacao farmers in Southwestern Nigeria for erythrocyte acetylcholinesterase enzyme (AChE) activity is desirable, and should be institutionalized so as to prevent incidents of unintentional and undetected acute and/or chronic insecticide poisoning among farmers. Also, it is desirable to check the hemoglobin level in the blood of the farmers so as to ensure that the hemoglobin level has not been adversely depressed due to exposure. The study confirmed that cacao farmers in southwestern Nigeria are indeed occupationally exposed as earlier opined by Sosan and Akingbohunge 2009 (6) and strengthens the need for awareness training on hazard and measures of preventing exposure.

Non-enzymic antioxidants such as reduced glutathione, vitamin C and vitamin E play an excellent role in protecting the cells from oxidative damage (7).

Nwanjo and co-workers (8) found decrease concentration of non-enzymic antioxidants namely Vitamine C and Vitamine E along with elevated lipid peroxide levels in hypertensive patients in Nigeria. This may implicate the environmental toxicants and increased oxidative stress as having significant public health implication in the incidence and prevalence of metabolic disorders in Nigeria.

Type 2 diabetes mellitus (T2DM) is the most common type of diabetes, contributing more than ninety percent of diabetes mellitus worldwide (9). The prevalence rate is rising rapidly particularly in the developing world. The prevalence of diabetes is between 0.6-7.2% in Nigeria (10).

## Challenges of biomonitoring in Africa: the Nigerian experience

While Blood Lead Levels (BLLs) in many western countries have progressively declined over the years, in Nigeria high BLL continue to be documented not only in exposed workers but also in “unexposed” control subjects. In an initial attempt to address the problem of environmental lead exposure which has hitherto gone unaddressed by both researchers and health policy makers in Nigeria despite the immense public health importance, Orisakwe (2009) reported high levels of BLL even in unexposed college students who served as control subjects in an occupational study in South Eastern Nigeria (11).

In two recent studies of heavy metals in blood of paint factory workers and artisans in South Eastern Nigeria (Table 1), we found BLL of  $17.00 \pm 4.0$   $\mu\text{g/dL}$  in control subject samples collected from secondary schools students (12) and  $35.0 \pm 7.9$   $\mu\text{g/dL}$  in controls samples collected from undergraduate medical students (13). Though these values were significantly lower than the  $59.6 \pm 15.9$  and  $42.00 \pm 4.0$   $\mu\text{g/dL}$  seen amongst the occupationally exposed

workers in these studies (12,13), the control value exceeded the US Environmental Protection Agency's (EPA) 10 µg/dL action dose. In another study where mainly office workers served as controls in an occupational cohort, the mean BLL of the occupationally exposed subjects was 48.50 ± 9.08 µg/dL, while the mean value in the control subjects was 33.5 ± 10.09 µg/dL (14).

Lead exposure is a major health risk factor in all Nigeria communities, both rural and urban. Prevention remains the best option for reducing lead exposure. The high blood lead levels seen in non-occupationally exposed in various studies conducted at different times and in various parts of Nigeria underscore the extent of environmental lead pollution in Nigeria. High BLLs in the same population cast doubt on the ease of sourcing "real unexposed control subjects" in future studies (11).

**Table 1. Blood lead level (BLL), serum cadmium and nickel levels of exposed and unexposed subjects. Values are mean ± SEM, with statistically significant p<0.005 (adapted from 12).**

Group	BLL (µg/dL)	Cadmium (µg/dL)	Nickel (µg/dL)
Exposed	39.00 ± 4.00	13.00 ± 1.00	63.00 ± 6.00
Unexposed	17.00 ± 4.00	9.00 ± 2.00	25.00 ± 4.00

Insecticides, herbicides and fungicides constitute the major pesticides used in Nigeria. According to FAO (15), pesticide importation rose steadily from about 13 million dollars in 2001 to 28 million dollars in 2003 with insecticides accounting for about 32% of the imports. The bulk of the pesticides are in agricultural production for the control of noxious weeds, insect pests and diseases of crops. As the agricultural production system moves more and more from subsistence to market-oriented large scale farming, a concomitant increase in pesticide usage seems inevitable. Besides, insecticides are used in urban and suburban dwellings rather extensively as aerosols for the control of peridomestic pests (e.g. ants, cockroaches, mosquitoes and other nuisance flies); and as other formulations for the control of structural pests like termites, and other stored product pests.

Pesticide usage generally is fraught with problems of undesirable side effects and food chain involvement. Many pesticides pose substantial short and long-term health risks (16), and cause substantial environmental damage/contamination (17). They are known to disturb the biochemical and physiological functions of erythrocytes and lymphocytes (18). The adverse health effects include a series of chronic end-points including cancer (19, 20), neurotoxic (21), immunotoxic (22) developmental (5), endocrine (23) and reproductive (24) and neurobehavioural effects (25). This has led to the prescription of tolerances [(Maximum Residue Level (MRL) and Acceptable Daily Intake (ADI) as well as No Observable Adverse Effect Level (NOAEL)] for various pesticides in food and water, especially by the Codex Alimentarius Commission, and other designated authorities in several developed countries of the world like the US Environmental Protection Agency.

Biological monitoring of exposure can be carried out by determining intact compounds or their metabolites in the blood serum, plasma or urine (26). Much work has been done on pesticide residues and its cumulative effect on human beings in the developed countries. For example, the residues of HCH, DDE and DDT have been shown to produce hazardous effects in humans (27). In less developed countries such as Pakistan, the presence of pesticide residues has been reported in the blood of Karachi people (28). In 2003 Cruz *et al.* (29) also reported the presence of pesticide residue in an urban and two rural populations in Portugal while the effect of pesticide residues on health and different enzyme levels in the blood of farm workers from rural area of Karachi, Pakistan was reported by Azmi *et al.* in 2006 (30).

In Nigeria, apart from the work of Ivbijaro (31) which evaluated insecticide residues in kolanuts, there seems to be no monitoring of pesticide residues in the country. Cacao farmers in Nigeria have a long history of pesticide usage on their farms. Cacao being a plantation crop had been subjected to large volumes of insecticides annually since 1957 especially for the control of the brown cacao mired. These insecticides included at various times till present, lindane (c-BHC), endosulfan or thiodan (6,7,8,9,10,10-hexachloro-1,5,5a, 6,9,9a-hexahydro-6,9-methano-2,4,3-benzodioxathiepin-3-oxide), diazinon {O,O-diethyl-O-[6-methyl-2-(1-methylethyl)-4-pyrimidinyl] phosphorothioate}, propoxur(2-isopropoxyphenyl-N-methylcarbamate) and dioxacarb {2-(1,3-dioxolan-2-yl)-phenylmethylcarbamate}.

Several of the cacao farmers have been involved in the pesticide spraying operations on their cacao farms for variable periods of 5 to over 20 years; but none has ever had their blood or domestic water source analyzed for pesticide residues. It was not until 2008 that Sosan *et al.* (32) reported investigations carried out on cacao farmers in selected villages of Osun and Ondo States of Nigeria. Authors concluded as follows: cacao farmers have been occupationally exposed due to the use of insecticides for mirid control in their plantations. In view of the types of insecticides commonly used and the residues detected in their blood serum and domestic water sources, there is a need to revitalize the pesticide regulation in Nigeria. The Regulatory Agency needs to become more alive to its responsibilities in enforcement and the prescription of standard safety measurements such as Acceptable Daily Intake (ADI) and No Adverse Effect Level (NOAEL) for various pesticides being used in the country. This sermon sounds like a tantrum which is lurked up and confined in the marooned cocoon of the labyrinthine of academic literature which the policy makers/regulatory bodies have willfully chosen not to read or be converted. Environmental justice and advocacy might be the only viable option through awareness created by organization of town hall meetings where such startling findings of public health importance will be conveyed to the local population in mitigated scientific language.

## **Biomarkers of exposure to mycotoxins: the African perspectives**

The currently favored method of measuring human exposure consists of the analysis of body fluids for the presence of aflatoxin derivatives (33, 34). Recent exposure to aflatoxin is reflected in the urine as directly excreted AFM<sub>1</sub> and other detoxification products, but only a small fraction of the dose is excreted in this way. Measurements of aflatoxin and its byproducts in urine have been found to be highly variable from day to day, which reflects the wide variability in the contamination of food samples, and, for this reason, the measurement of AFM<sub>1</sub> on a single day may not be a reliable indicator of a person's chronic exposure (33-35). The aflatoxin-albumin adduct is measured in peripheral blood and has a half-life in the body of 30-60 days. Therefore, it is a measure that integrates the exposure over a longer period and hence is a more reliable indicator of a person's chronic exposure. Data relating to biological exposure (Table 2) are relatively rare, because the locations of such measurements are mainly in West Africa.

These data show major variations in seasonal exposure (36), which reflects the natural development of contamination in storage. These biomarker data show that, regardless of food preparation practices, the human populations of these developing countries are widely and significantly exposed to aflatoxin.

Given that little is done to decontaminate foods in most sub-Sahara Africa, it is likely that the prevalence of chronic exposure in most countries is similar to that measured in these studies with the use of biomarkers.

**Table 2. Biomarkers of exposure to aflatoxin in humans**

Country	Exposure rate (%)	Range or test type	Reference
Benin	99	5–1064 pg/mg <sup>*</sup>	36
Gambia	95	0–720 pg/mg	37
Guinea	90	0–385 pg/mg <sup>*</sup>	38
Nigeria	40-90	Lung autopsies	39
Sierra Leone	95-99	Aflatoxin in urine	40
Sudan, Zimbabwe, Ghana, Liberia, Kenya, Transkei (South Africa)	32 99	Aflatoxin in urine Liver biopsy of kwashiorkors	41 41

\* pmol aflatoxin-albumin/mg albumin

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# PLANTS AS SOURCE OF DETOXIFYING AGENTS AND NUTRACEUTICALS IN AFRICA

Assob Nguedia Jules Clement, Asongalem Emmanuel Acha, Ngounou Elionore  
*Faculty of Health Sciences, University of Buea, Cameroon*

## Introduction

Traditional medicine as a major African socio-cultural heritage has been in existence for hundreds of years. It was once believed to be primitive and wrongly challenged by foreign religions dating back during the colonial rule in Africa and subsequently by the conventional or orthodox medical practitioners (1). The traditional medicine has been the focus for wider coverage of primary health care delivery in Africa and the rest of the world (2).

The new health agenda in Africa in general and Cameroon in particular focuses on the institutionalization of traditional medicine in parallel with orthodox medicine into the national health care scheme in order to move the health agenda forward since effective health cannot be achieved in Africa by orthodox medicine alone unless it has been complemented with traditional medicine (2).

Cures for a number of severe diseases are not yet available despite rapid progress in medical research over the past decades. Many chronic diseases such as rheumatoid arthritis, psoriasis, and ulcerative colitis, all with an inflammatory and/or immunological background, are treated symptomatically – no drug is available to effectively cure them.

People are constantly exposed to poisonous agents found in their immediate environment; air, water, food, drugs, infections and various chemical agents.

Annually, approximately 8 million people are poisoned, 600,000 attempt suicide, accounting for 11,894 deaths and 218,500 hospitalizations (3). These toxic agents which are usually absorbed by inhalation, oral routes and skin contacts, must be removed from the body. Among various mechanism used by the body to get rid from these agents, we have drug metabolism by the liver, urinary excretion, vomiting and so on. In modern medicine an attempt to assist body's struggle is through gastric decontamination, by use of emetic agents or lavage, use of activated charcoal and the use of cathartics to hasten excretion and thereby limit absorption. Skin decontamination is usually performed when percutaneous absorption of a substance may result in systemic toxicity or when the contaminating substance may produce local toxicity effects (e.g. acid burns). In this case person clothing is removed and the areas are irrigated with copious quantity of water. Forced diuresis and urinary pH manipulation, dialysis and hemoperfusion are used in more difficult systemic intoxication cases (3). Envenomations due to snake bites are commonly treated by parenteral administration of horse or sheep-derived polyclonal antivenoms aimed at the neutralization of toxins (4).

These arrays of measures are available only in health centres where well trained personnel work and available drugs and equipments are found. Unfortunately majority of people lack access to health care, and even where it is available, the quality is largely below acceptable levels. This situation is further exacerbated by sever financial constraints, the high debt burden, a rapidly growing population, political instability, high inflation rates, declining real income and deteriorating growth rates. Many Africans, especially rural people and the urban poor, rely on the use of herbal medicine when they are ill. In fact, many rural communities in Africa and in Cameroon in particular, still have areas where traditional herbal medicine is the major and in

some cases the only source of health care available. Because of the nature of their activities, majority of the population who are farmers, hunters, and fisher men and women are daily exposed to poisonous agents such as snake and scorpion bites, consumption of poisonous food or herbs, auto medication.

This chapter summarizes the currently available knowledge on Cameroonian plants used to handle intoxication cases, and the efficacy of plant-derived extracts and compounds as detoxifying agents. This review will focus on ethnopharmacological studies of medicinal plant used traditionally for cases of poisoning, food poisoning, and snake bites, night poisons, as purgative agents, hepatitis and yellow fever. We will further investigate the presence of important classes of secondary metabolites in the families of these plants with available literature possible on their pharmacological properties as emetics, diuretics, cathartics, antiradicals, antioxidants and anti-inflammatory agents. This study also provides tools for further research, in order to contribute for the search of detoxifying agents and valorization of "health foods" from the Cameroonian folk medicine.

## **Medicinal plants used to manage cases of intoxication by traditional medical practitioners in Cameroon**

Adjanohoun *et al.* (5) provided a useful review of the traditional use of medicinal plants in Cameroon, although much work remains to be done regarding the documentation of existing ethnobotanical knowledge. Jiofack *et al.* (7) also documented the traditional use of 289 plants species belonging to 89 families against 220 pathologies. Table 1 presents a compendium of medicinal plants used in various parts in Cameroon to manage cases of intoxication by traditional medical practitioners. Using their nomenclature, 47 different species belonging to 26 families are used to manage various intoxication cases including situation of poisoning, food poisoning, body cleansing, immune system booster, hepatitis, snake bites, hepatic failure, renal pains, use to prevent poisoning, night poison and as purgative. The various plant parts are barks, leaves, roots, dry seeds, leafy shoots, terminal buds, fruits, juice, latex, bulbs which are used in form of decoction, maceration, infusion, seed ashes mix with palm oil, intranasal drops or patients asked to chew leafy parts to induced vomiting. In order to understand the mechanism of action of these various plants as detoxifying agents' further research need to be done to explore their phytochemistry and their ability to counteract gastrointestinal tract, liver, heart, kidneys, lungs, brain and skin adverse agents. The presence of secondary metabolites like phenols which are used to detoxify blood from chemicals and harmful toxic agents should be assessed. Managing intoxication also takes into account the inflammatory process that accompanied it. In this case the presence of saponins and flavonoids with anti-inflammatory properties may be important. Alkaloids and saponins in some plant extracts may prevent absorption of harmful chemical through the intestinal lining of the gut. Another possible way of fighting against liver intoxication is that saponins can bind irreversibly to harmful chemical which are eliminated through secretion in the bile duct. The presence of terpenoids in the oil from some seeds is applied externally for skin diseases (7) and this is due the fact that terpenoids can strengthen the skin, by increasing the concentration of antioxidants in wounds, and restoring inflamed tissues through increasing blood supply (8). The following section therefore presents previous studies on the phytochemistry and pharmacological properties of some medicinal plant listed in the Table 1 as detoxifying agents.



**Table 1. Medicinal plants (in alphabetic order) used to manage cases of intoxication by traditional medical practitioners in Cameroon**

Plants or substances	Family	Usage	Plant parts	Preparation	Ref.
<i>Achrantes aspera</i> linn	Amaranthaceae	Poisoning	Leaves, flowers	Infusion	5
<i>Ageratum conyzoides</i>	Asteraceae	Poisoning	Leaves	Decoction	5
<i>Aloe schweifurthei</i>	Liliaceae	Food poisoning	Leaves	Maceration	5
<i>Alstonia boonei</i>	Apocynaceae	Snake bite	Latex	Apply on wounded site of bite	5
<i>Aneilema lanceolatum</i>	Commelinaceae	Poisoning	Bark	Wash and massage of hands and legs with decoction	5
<i>Baillonella toxisperma</i> Pierre	Sapotaceae	Kidney pain	Bark	Decoction	6
<i>Begonia</i> sp	Begoniaceae	Night poison	Fruit, bark	Decoction	7
<i>Boswellia dalzielii</i>	Burseraceae	Snake bite	Root	Decoction	7
<i>Cassia alata</i>	Cesalpiniaceae	Yellow fever	Leaves, roots	Decoction	7
<i>Cayratia gracilis</i>	Vitaceae	Poisoning	Leafy stem	Decoction, bath	5
<i>Ceiba pentadra</i>	Bombacaceae	Purgative	Bark, leaves, roots	Decoction	7
<i>Chrysantephylium indicum</i>	Asteraceae	Snake bite	Juice	Apply on wounded site of bite	5
<i>Chrysanthelium indicum</i>	Asteraceae	Hepatitis	Whole plant	Decoction	5
<i>Commelina benghalensis</i>	Commelinaceae	Poisoning	Leaves	Decoction	5
<i>Crinum jagus</i> *	Amaryllidaceae	Poisoning	Leaves	Chew half a leaf to induce vomiting immediately	5
<i>Crinum natans</i>	Amaryllidaceae	Poisoning	Bulbs	Decoction	5
<i>Crinum zeilanicum</i>	Amaryllidaceae	Snake bite	Leaves and rhizomes	Drink infusion mixture	5
<i>Dacryodes edulis</i>	Burseraceae	Snake bite	Leaves	Plaster	7
<i>Dioscorea bulbifera</i>	Dioscoreaceae	Poisoning	Roots, bulbs	Powder, decoction	7
<i>Dioscorea bulbifera</i>	Dioscoreaceae	Prevent poisoning			5
<i>Elephantropus mollis</i>	Asteraceae	Snake bite	Leaves	Apply on wounded site of bite	5
<i>Ficus exasperate</i>	Moraceae	Poisoning	Leaves	Decoction	7
<i>Ficus thonningii</i>	Moraceae	Hepatitis	Leaves	Decoction	5
<i>Garcinia lucida</i>	Dioscoreaceae	Poisoning	Dry seeds	Chew	5
<i>Glyphae bravis</i>	Tiliaceae	Hepatitis	Leaves	Decoction	5
<i>Glyphae brevis</i>	Tilacea	Poisoning	Leaves	Decoction	5

to be continued

continues

Plants or substances	Family	Usage	Plant parts	Preparation	Ref.
<i>Halea stipulosa</i>	<i>Rubiaceae</i>	Hepatitis	Bark	Decoction	5
<i>Harungana madagascariensis</i>	<i>Hypericaceae</i>	Poisoning	Bark , leaves	Decoction	7
<i>Isoblerlinia docka</i>	<i>Cesalpiniaceae</i>	Food intoxication	Bark	Decoction	7
<i>Laportea ovalifolia</i>	<i>Urticaceae</i>	Poisoning	Leafy stem	Decoction	7
<i>Leucas martinicensis</i>	<i>Lamiaceae</i>	Hepatic failure	Leaves	Decoction	5
<i>Lippia multiflora</i>	<i>Verbenaceae</i>	Body cleansing, immune system booster			7
<i>Ocimum basilicum</i>	<i>Lamiaceae</i>	Body cleansing, immune system booster			7
<i>Phyllanthus amarus</i>	<i>Euphorbiaceae</i>	Snake bite	Leafy shoot		5
<i>Piper umbellatum</i>	<i>Piperaceae</i>	Snake bite, poisoning	Leaves	Apply on wounded site of bite, prevent poisoning	5
<i>Portulaca oleracea</i>	<i>Portulacaceae</i>	Poisoning	Leafy stem	Decoction	7
<i>Prunus africana</i>		Body cleansing, immune system booster			7
<i>Ricinus communis</i>	<i>Euphorbiaceae</i>	Poisoning	Seeds	Seed ashes mix with palm oil	5
<i>Sarcocephalus latifolius</i>	<i>Rubiaceae</i>	Hepatitis	Roots	Decoction	5
<i>Securidaca longepedunculata</i>	<i>Polygalaceae</i>	Snake bite	Leaves	Decoction	7
<i>Senna alata</i>	<i>Leguminosae</i>	Food poisoning	Terminal buds	Maceration	5
<i>Senna italic</i>	<i>Leguminosae</i>	Food poisoning	Leaves	Cold infusion	5
<i>Solanum dasyphyllum</i>	<i>Solanaceae</i>	Food poisoning	Leaves	Grind heated leave mix in palm oil	5
<i>Solanum torvum</i>	<i>Solanaceae</i>	Poisoning	Fruits and roots	Maceration	5
<i>Tetrapleura tetraptera</i>	<i>Mimosaceae</i>	Poisoning	Roots	Drops of root juice intra-nasally	5
<i>Vernonia amygdalinia</i>	<i>Asteraceae</i>	Poisoning	Leaves	Decoction	7
<i>Voacanga africana</i>	<i>Apocynaceae</i>	Poisoning	Leaves	Decoction	5

## Phytochemistry and pharmacological properties

In Cameroon and Congo, traditional use of *Ageratum conzyoides* is used to treat fever, rheumatism, headache, and colic (9, 10). The secondary metabolites of *A. conzyoides* include flavonoids, alkaloids, coumarins, essential oils, and tannins. The alkaloids are mainly of the pyrrolizidinic group, which suggests its important hepatoprotective activity (10, 11).

The study of the pharmacological activity of *Achranthes aspera* have revealed a number of properties among which can be cited their use as juvenile, astringent, emetic, spasmolytic, diuretic, purgative, effect on urinary tract (12). This plant is also known to possess abortifacient and contraceptive properties, and hence should be avoided during pregnancy. However, the drug is devoid of any side effect up to the dose of 8 g/kg, orally in rabbits (12). The probable mechanism of action of plant may lie in its ability to increase elimination of toxic chemical from the blood through increased diuresis.

A study carried out in Nigeria on *Alstonia boonei* revealed the presence of alkaloids, tannins, saponins, flavonoids and cardiac glycosides as phytochemicals detected together with the important vitamin, ascorbic acid and minerals like calcium, phosphorus, iron, sodium, potassium, and magnesium. The plant was also found to be an important scavenging agent (14). *Alstonia boonei* (*Apocynaceae*) is used by different sellers for treating typhoid fever, jaundice and malaria (15, 16). The presence of ascorbic acid may account for its free radical scavenging property, therefore reducing oxidative stress in the liver.

*Aloe vera* is used in the Northwest west region of Cameroon to treat malaria, gastritis, stomach ache, wounds and skin diseases (16).

A study carried out in Nigeria on air-dried leaves of *Boswellia dalzielii* Hutch has indicated monoterpenoids ( $\alpha$ -pinene, 45.7%, and  $\alpha$ -terpinene) as major compounds found on its essential oil. In another study, the aqueous extract of *Boswellia dalzielii* presented a dose dependent reduction in acetylsalicylic acid induced ulceration (17). This probably suggests the presence of some active ingredients which act through one or more ulcer protecting mechanisms. The results obtained were comparable to that of cimetidine which has been reported to have ulcer healing mechanism involving competitive inhibition of H<sub>2</sub> receptors (18, 19). Emphases on the presence of chemical compounds like saponins which has been reported in Asia as gentle blood cleanser and in the prevention of cell's damages by free radicals should be envisaged.

Study on *Cassia alata* in India has revealed its high phenolic and flavonoids content and its important antioxidant activity (20). Other studies have shown their laxative properties (21); Cassiaindoline is a new dimeric indole alkaloid isolated from *Cassia alata* L. leaves. It exhibited analgesic activity at a dosage of 125.0 mg/kg in mouse and decreased the number of writhings induced by acetic acid by 49.4% (22). These arrays of pharmacological properties could account for its use in traditional folk medicine as antidote in case of ingestion of poisonous agents.

*Cayratia japonica* (*Vitaceae*) was found to contain luteolin (luteolin-7-O-beta-D-glucopyranoside). Luteolin is one of the most common flavonoids present in edible plants and in some medicinal plants to treat a wide variety of pathologies (23). The action of flavonoids as anti-inflammatory, anti-oxidants may justify its hepatoprotective property.

The presence of terpenoid is also another reason why *Centella asiatica* is used as a rejuvenating agent because it has been found to be a very useful remedy for anti-aging and overall beauty enhancement (24). From clinical studies, it is shown that terpenoids strengthen the skin, increase the concentration of antioxidants in wounds, and restore inflamed tissues by increasing blood supply. Cardiac glycosides found in *Centella asiatica*, is a compound that has been shown to aid the treatment for congestive heart failure and cardiac arrhythmia. Cardiac glycosides work by inhibiting the Na<sup>+</sup>/K<sup>+</sup> pump. This causes an increase in the level of sodium ions in the myocytes, which then leads to a rise in the level of calcium ions. This inhibition

increases the amount of Ca<sup>2+</sup> ions available for contraction of the heart muscle, and hereby improves cardiac output and reduces distention of the heart (25).

*Lippia multiflora* is used in Cameroon folk medicine as a cleansing agent and as a immune system's booster, a study conducted on dried leaves of *Lippia multiflora* (26) isolated ursolic acid, n-tritriacontane and (salvigenin). *L. multiflora* contains triterpenoid, saponins possessing oleanolic acid as aglycone, as major chemical constituents. Other constituents of the plant are ecdysterone, long chain alcohol, viz. 17-penta triacontanol, 27-cyclohexyl heptaosan-7-ol, 16-hydroxyl 26-methyl heptacosan-2one and 36, 47-dihydroxy hen-pentacontan-4one. It also contains a water soluble base, betaine (27, 28).

The study of the chemical composition has shown that active constituents of the lipophilic extract of Cortex of *Prunus africana* include docosanol (0.6%) and  $\beta$ -sitosterol (15.7%). Other major constituents include: alkanols – tetracosanol (0.5%) and trans-ferulic acid esters of docosanol and tetracosanol; fatty acids (62.3%, comprising myristic, palmitic, linoleic, oleic, stearic, arachidic, behenic and lignoceric acids); sterols -sitosterone (2.0%) and daucosterol; and triterpenes -ursolic acid (2.9%), friedelin (1.4%), 2- $\alpha$ -hydroxyursolic acid (0.5%), epimaslinic acid (0.8%) and maslinic acid. Proven pharmacological activity on animal studies of *Prunus africana* include increase of prostate secretion, anti-inflammatory, antispasmodic, inhibition of cell proliferation, effect on human benign prostatic hyperplasia, justifying its use as an antidote (30).

A study carried out in Nigeria indicates that the aqueous extract of *Portulaca oleracea* possesses unique skeletal muscle relaxant properties (31). *P. oleracea* is listed as a treatment for parasites, a blood-cleanser, and to refresh the digestive system. The plant is to be fed fresh (after it has seeded) ad lib. It contains many biologically active compounds and is a source of many nutrients. Some of the biologically active (and, in some case, potentially toxic compounds) include free oxalic acids, alkaloids, omega-3 fatty acids, coumarins, flavonoids, cardiac glycosides, and anthraquinone glycosides. It has high contents of Omega-3 fatty acids and protein (compared to other vegetables). The relaxant effect of this plant has also been observed on smooth muscle tissue and as potent anti-cancer drug (32).

*Piper umbellatum* and *Piper peltatum*, plants utilized in traditional medicine, demonstrated moderate inhibitory ability towards enzymatic and toxic activities of purified phospholipase A2 myotoxins of Bothrops snake venoms by a compound known as 4-nerolidylcatechol (33). This could explain the use of *P. umbellatum* in Cameroon folk medicine as an antidote against snake bite.

*Sarcocephalus latifolius* contains favonoids, alkaloids, carbohydrates, tannins and saponins. Tests on mouse have shown a dose dependent decrease of Alanine transaminase (ALT), Aspartate transaminase (AST), total and conjugated bilirubin levels (P<0.05) across all the groups on CCL4 induced hepatotoxicity (34). This study therefore confirmed the hepatoprotective properties of the plant.

*Vernonia amygdalina* is rich in flavonoids and glycosides. It is a Nigerian edible vegetable who's both aqueous and ethanolic leaves' extracts showed significant anitibacterial activity against *E. coli*, *Staphylococcus aureus*, *Bacillus cereus*, *Shigella dysenteriae* and *Salmonella typhimurium* (35). This could explain their usage in folk medicine as antidote against food poisoning. Although treating gastroenteritis as a result of food intoxication with various crude preparations may not be effective because once the pathogens produce a sufficient amount of toxin in the food, it is the toxin and not the pathogen that cause the disease after ingestion of the contaminated food. In many cases, extracts of active constituents that are effective *in vitro* experiments may not show the same effectiveness when applied *in-vivo*. Other studies have provided evidence that *Vernonia amygdalina* extracts represent a DNA-damaging anti-cancer agent against breast cancer and its mechanisms of action functions, at least in part, through minimal DNA damage and moderate toxicity in tumors cells (36).

Previous studies have shown that the fruit of *Tetrapleura tetraptera* (Taub) (family: *Fabaceae*) is widely used in African traditional medicine for the management and/or control of an array of human ailments, including schistosomiasis, asthma, epilepsy, hypertension and so on. Studies on experimental animal indicate that *Tetrapleura tetraptera* (Taub) fruit aqueous extract (TTE) possesses analgesic and anticonvulsant properties (37). *Tetrapleura tetraptera* contains tannin (0.36%), saponin (0.54%); flavonoid (0.84%); alkaloid (1.28%), phenol (0.42%) and hydrocyanic acid (HCN). Both water and ethanol extracts have shown strong antibacterial activity (Inhibition diameter varying between 11-26 mm) against *Escherichia coli*, *Staphylococcus aureus*, *Salmonella typhi* and *Pseudomonas aeruginosa*. Because of its content in HCN, it should be used with care.

*Securidaca longepedunculata* contains gallic acid, flavonoid, catechin, anthocyanin, cyanidin-3-glycosyl and condensed tannins and catechin. Quercetin (0.98 mg/mL) is the major compound found in plant. Its IC<sub>50</sub> value reached 5.5 µg/mL, revealing that the root barks of *S. longepedunculata* have a very high antioxidant and anti-inflammation properties (38).

*Voacanga* is used to treat or cure a wide range of diseases in Africa. The alkaloids are the principal bioactive compounds responsible for its use in traditional medicine. The major alkaloids include voacamine, voacangine, vobasine, and ibogaime. Others include voacristine, voacamidine, voacarine, voaphylline, vobtusine, voalfolidine and tabersonine (39).

Jiofack *et al.* (7) study numbers of herbal drugs through direct interview or traditional healers who recommend the use of 2 to 3 months long phytotherapy with *Aloe vera*, *Lippia multiflora*, *Ocimum basilicum* and *Prunus africana* to clean up primarily the body and prevent the collapse of immune system while using subsequent medical therapy.

A variation in the chemical composition of the essential oils of different organs of domesticated *Lippia multiflora* Moldenke was studied (40). *Lippia multiflora* Moldenke, analysed by GPC-FID and GPC-MS, were found to be rich in monoterpenes.

Leaves and flowering parts of *O. basilicum* are traditionally used as antispasmodic, aromatic, carminative, digestive, galactagogue, stomachic, and tonic agents (41). They have been also used as a folk remedy to treat various ailments such as; feverish illnesses, poor digestion, nausea, abdominal cramps, gastro-enteritis, migraine, insomnia, depression, gonorrhoea, dysentery, and chronic diarrhoea exhaustion. A study carried out in Nigeria (University of Maiduguri) on *Ocimum basilicum* revealed that the aqueous leaf extract concentration of saponin and alkaloids were high, flavonoids, terpenes and steroids were present in medium quantity, while traces of tannins and carbohydrates were also present in the aqueous extract (42).

The study also revealed that the phytochemical investigation of the various solvent (chloroform, ethyl acetate and n-butanol) fractions contain carbohydrates, terpenes and steroids, tannins and flavonoids. In addition, the chloroform and n-butanol fractions contain cardiac glycosides. The result showed high concentration of Na, K and SO<sub>4</sub>, while those present in trace quantity include Mg, Mn, Zn, Cu and Pb. The extracts of *O. basilicum* were found to possess *in vitro* antibiotic activity against *Staphylococcus aureus*, streptococcus species, salmonella species, Shigella species, and *Pseudomonas aeruginosa* at high doses. In conclusion, this study has shown that *Ocimum basilicum* contain chemical elements that can be pharmacologically useful as well as possess some antibacterial properties (43) studied the antibacterial effects of the leaves derived calli of *Ocimum basilicum* L. The result of the study revealed that the ethanolic extracts of leaves derived calli of *O. basilicum* can be used in the treatment of boils, sores and wounds, since *P. aeruginosa* have been implicated as causative agents of these diseases. The pathogen *S. typhi* is known to cause fever and food borne illness. The ethanolic extract of leaves derived calli of *O. basilicum* show the inhibitory activity against the bacterium *S. typhi* and thus the study confirms the presence of active constituents present in these plants.

## Health foods (nutraceuticals) and their antioxidant properties in Cameroon folk medicine

If there are insufficient quantities of antioxidants to match its exposure to free radicals then the body is said to be in a state of oxidative stress. In this state, unimpeded free radicals cause damage that can lead to inflammation, immune dysfunction, DNA damage and, potentially, a whole range of degenerative diseases (44).

In a continuous state of oxidative stress, we generally experience this unhealthy condition on a regular basis as it can be precipitated by a wide range of factors. These include psychological stress, infections, drugs, smoking, pollution, radiation, excessive exercise and obesity. Therefore we can all benefit from a regular intake of an array of antioxidants that can “mop up” excess free radicals as they are introduced into, and produced by, our bodies. Moreover, as many antioxidants are inactivated during the process of free radical neutralization, they need to be continually replenished. Our bodies do some of the work by producing their own antioxidants, but we need to supplement these with food-based compounds.

### Nutraceuticals in Cameroonian diet

Dietary spices are a heterogeneous collection of a wide variety of volatile and non-volatile chemicals obtained from dried aromatic parts of plants—generally the seeds, berries, roots, pods, and sometimes from leaves. Populations that use spices and/or herbs in their diets have been shown to have lower incidences of chronic disease (45).

One benefit of spices and herbs is that they contain bioactive components such as polyphenols that can reduce oxidative stress and modulate harmful biological pathways, thereby reducing chronic diseases. Polyphenols also offer an attractive strategy to control postprandial hyperglycemia, assist in weight management, and in the management of CardioVascular Diseases (CVD), with minimal side effects. Various polyphenols have been reported to show radical scavenging activity (46) as well as inhibiting  $\alpha$ -amylase and glucosidase activities (47) all involved in the management of weight gained. A study carried out by Oben *et al.* (48) revealed that many plants (19) are used as spices in Cameroon. Three of which were found to have an important content of phenolic compounds; amongst these plants *Dichrostachys glomerata*, *Xylopi*a *parviflora* and *Tetrapleura tetra*ptera, had the highest content of phenolic compounds. The presence of free radical scavenging agents in six species, namely *Dichrostachys glomerata* (87.58%), *Tetrapleura tetra*ptera (83.94%), *Xylopi*a *parviflora* (90.55%), *Xylopi*a *aethiopica* (54.72%) and *Fagara xanthoxyloides* (48.82%) was of great interest. On the hand, spices have shown anti-amylase activities as *Aframomum daniellii*, *Hypodapnis zenkeri*, *Echinops giganteus*, *Aframomum citratum*, and *Xylopi*a *aethiopica*, while those of moderate potency were *Monodora myristica* (with husk and without husk), *Fagara leprieurii*, *Fagara xanthoxyloide*, *Scorodophloeus zenkeri* (barks and seeds without husk), *Aframomum aulacocarpus* (with husk), *Solanum melongena*. *Xylopi*a *aethiopica*, was considered an important inhibitory property against amylase, while the seeds' extract of *Scorodophloeus zenkeri* (with husk) is only moderately potent. This anti-amylase is probably due to the presence of phenolic compounds, which have been shown to interact with and/ or inhibit enzymes (49, 50).

The antioxidant mechanisms of action include the scavenging reactive oxygen and the nitrogen free radical species, decreasing the localized oxygen concentration and thereby reducing the molecular oxygen's oxidation potential, metabolizing lipid peroxides to non-radical products and the chelating metal ions to prevent the generation of free radicals. In this

way, antioxidants limit free radicals from oxidizing Low-Density Lipoprotein (LDL) cholesterol. Oxidized LDL may increase the risk of atherosclerosis, promoting platelet adhesion, which can lead to thrombosis thereby increasing the risk of heart disease or stroke. Damages of cell's DNA, may lead to cancer, therefore blocking the normal endothelial cell function and vasodilatation in response to nitric oxide (NO), a potential mechanism for heart disease and cancer, triggering inflammation and impairing immune function.

## Closing notes

The review of Cameroonian medicinal as potential detoxifying agents and nutraceuticals is intended to serve as the scientific baseline information for the use of the documented plants, as well as a starting point for future studies, leading to the production of improved phytomedicines. The chapter also draws attention to some active metabolites, which could probably explain the mechanism of action of many plants used in Cameroon folk medicine to solve problems of intoxication. Some of the Cameroonian plant extracts are good sources of detoxifying agents and nutraceuticals. This study have revealed the important biological properties of *Achrantes aspera* (diuretic), *Alstonia boonei* (free radical scavenger), *Boswellia dalzielii* (anti-ulcer), *Cassia alata* (analgesic and antioxidant), *Cayratia japonica* (anti-inflammatory and antioxidant), *Centella asiatica* (treatment of congestive heart failure and cardiac arrhythmia), *Lippia multiflora* (cleansing agent and as a immune system's booster), *Prunus africana* (increase prostate secretion, anti-inflammatory, antispasmodic, inhibition of cell proliferation), *Portulaca oleracea* (skeletal muscle relaxant properties, blood-cleanser), *P. umbellatum* (antidote against snake bite through its inhibitory ability on phospholipase A2 of snake venom), *Sarcocephalus latifolius* (antihepatotoxic), *Vernonia amygdalina* (anticancer, and food poisoning), *Tetrapleura tetraptera* (analgesic and anticonvulsant), *Voacanga African* (antihypertensive), and *Securidaca longepedunculata* (anti-inflammatory and antioxidant). These important biological properties confirm their use in Cameroon traditional medicine as detoxifying agents in situations such as food poisoning, and snake bites, night poisons, as purgative agents, hepatitis and yellow fever. This is justified by their content in important metabolites such as flavonoids, polyphenols, alkaloids, anthraquinones, triterpenes and saponins.

With regards to nutraceuticals or health foods, these are common in Cameroonian diet. Six of these spices are found to be rich in free radical scavenging agents, namely *Dichrostachys glomerata*, *Tetrapleura tetraptera*, *Xylopi parviflora*, *Xylopi aethiopica*, and *Fagara xanthoxyloides*, whereas other plants like *Aframomum aulacocarpus* (with husk), *Solanum melongena* and *Xylopi aethiopica* have important inhibitory property against amylase. This is important in managing weight and risk factors of cardiovascular diseases. The determination of probable mode of action of these extracts helps explain their therapeutic profile. The safe and stable herbal extract may be marketed if its therapeutic use is well documented in traditional folk medicine, as also recommended by the World Health Organization.

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# COMMUNITY HEALTH RISK PERCEPTION, BEHAVIORAL EXPOSURE AND RISK COMMUNICATION

Wilfred Angie Abia (a), Guy Bertrand Pouokam (b)  
(a) *Integrated Health for All Foundation (IHAF), NPO/NGO, Cameroon*  
(b) *Faculty of Science, University of Yaoundé I, Cameroon*

## Introduction

Individuals, just like communities, respond differently to information on harmful substances or situations around them. This is due to differences in perception of different individuals and communities. City dwellers are more exposed to harmful substances, e.g. chemicals, than rural populations. This is due to the numerous exposure routes in urban cities with an advanced state of industrialization. However, common to both communities is that the inhabitants, especially in developing nations such as Cameroon, are not aware and do not understand to various risk and degree of exposure whether occupational, natural or behavioral. This necessitates increased sensitization and capacity building on risk assessment, risk communication and risk management.

Basically, risk can be defined as the probability of adverse effects to occur. Mathematically, risk can be represented as:  $Risk = Hazard \times Exposure \times (Vulnerability \text{ or } Susceptibility)$ , where hazard refers to the intrinsic properties of a substance to cause harm, and exposure is a combination of facts that characterize the contact with the hazard.

Hazard refers to chemical or biological substances which may have an adverse or unacceptable effect(s) in the body when in contact with small or huge quantities and immediately or over a long period of time. Some commonplace hazardous substances with which people in Africa come in touch on day to day basis include chemical hazards (pharmaceutical waste) and biological hazards (HIV/AIDS) just to mention a few. Some of these hazards exist naturally (e.g. mycotoxins) in food.

Exposure is the process of getting in contact with substance(s) which may be harmful to the body either in little quantities (picked up immediately) or in large quantities (immediately or as a result of bioaccumulation). Some common routes of exposure include foods, the living environment (including occupational behaviours) and consumers' products (from food packaging to cosmetics to office accessories etc). The higher an individual is exposed to a chemical, the higher is the risk. Therefore, to reduce risk, exposure levels to hazardous substance should be minimized i.e. avoiding as much as possible chances of getting in contact with xenobiotics.

## Risk perception and behavioral exposure

With good perception of the probable risk we may be exposed to we stand a better chance of reducing the risk via reducing exposure levels. In rural communities where exposure to harmful substances is mostly linked to behavior, lifestyle or culture of the people; and their social economic situation, reduction of exposure and consequential risk requires much survey and research on the population.

## **Health risk communication at the community level**

It is a good thing to have a good perception of probable community risk. That is establishing a reasoned risk question, hazard characterization, exposure assessment, risk conclusion and management strategies. Even at that, it is more important to know how to communicate the situation for the deserving change to occur.

Risk communication could be seen as the most dependent factor based on which the exposure and consequential risk could increase or reduce. The understanding of the information communicated to the audience or population especially rural populations (with high level of illiteracy) is paramount. The media (journalist) and civil society actors are at the forefront of this vital factor. Use of figures and percentages as judgment or decision lines or marks should be handled with great care; else, the reverse of the intended information could be embraced.

This chapter basically focuses on the RAT of the IHAF and partners preliminary integrated risk-to-benefit assessment between social and cultural impact of the commonplace behavior(s) which may be modified and the community health outcomes at various local communities in Cameroon.

## **Risk perception and behavioral exposure in local communities**

Considering that risk is associated with almost all that we do in our day-to-day activities especially in rural settings, a united and friendly approach to reducing behavioral exposure levels is via raising awareness on probable risks. Unfortunately, indigenous populations generally seldom have access to knowledge and information, as well as education and communication on risk situations. The experiences of the Integrated Health for All Foundation (IHAF, Cameroon) shall be shared in this section. This shall include: lifestyle of indigenous people; associated risk; the peoples' perception of the risk; with sample case studies and recommendations.

## **Lifestyle of indigenous people and associated health risks**

In every community there are varied groups and subgroups categorized by nature of activity, age group, lifestyles etc. They have varied exposures and thus behave differently. Notwithstanding even those with similar exposures (in most cases) turn out to behave differently. What then could be accountable for these differences?

According to Mileti (1), risk perception is the subjective judgment that people make about the characteristics and severity of a risk. This is clearly the case of our (IHAF's) experience on the field where there is inadequate and in some cases complete absence of information, education and communication on exposure to potential risks via day-to-day doings. Generally, people respond to a risk or hazard in ways consistent to their perception of the risk situation. Thus, it is an individual's perception that influences his/her behavior or action. Therefore, the understanding of public perception of natural hazards is necessary in order to impact hazard preparedness. On the other hand, it could be a problem because residents of at-risk areas often have inaccurate beliefs about the hazard agent and its impacts, are unaware of available adjustments, and may have erroneous beliefs about the effectiveness of the adjustments of which they are aware (2). Research shows that adaptive actions are motivated by awareness of the hazard, knowledge of how it can affect the community, and feelings of personal vulnerability to the potential consequences (3).

However, frequent exposure to relevant information on hazards does not automatically elicit attention and comprehension, let alone the acceptance, personalization, and retention required to initiate hazard adjustments. Furthermore, Lindell and Perry (2) argued that people do not

actually need to understand the hazard(s) in order to be motivated enough to prepare, but they need to believe that the hazard(s) really exists and that protection is needed. Not only are the findings interesting and enlightening, they corroborates with IHAF's field experiences. Despite our participatory approach to problems/needs/desires identification and prioritization together with the community, we have continued to observe resistance from some individual(s) and or subgroup(s) in various communities. These subjects persist and stick to their same old ways not because they do not understand but because they are adamant to change, so called "anti-developments" in communities. As a matter of fact such groups should be handled with care as they are integral stakeholders in the needed behavioral/social changes in the community. We have always used their progress in the change decision as an indicator of success.

Despite the above, we strongly believe that some probable reasons as to why people respond slowly (or not at all) towards potential hazards in their day-to-day activities include the fact that:

- (i) they are not aware (lack access to proper Information, Education and Communications, IEC);
- (ii) they do not believe in the existence;
- (iii) there is poor communication on the hazard /exposure;
- (iv) there is misunderstanding of probability;
- (v) there is biased media coverage;
- (vi) there is misleading personal experiences which often cause risk to be misjudged, underestimated or overestimated.

Generally, risk perception is more frequently influenced by many factors. Risk perception research suggest that misunderstanding of probability, biased media coverage and misleading personal experiences often cause risk to be misjudged, under or overestimate [4]. Among these factors, we can cite: devastating consequences (e.g. dread), lack control, man-made (intentional) risk, degree of understanding, inflexibility of the situation, past experiences ("once beaten twice shy"), and others. For example:

*Dread.* Certain risks are more dreadful than others. A good example is cancer relative to malaria because cancer is observed as a terrible way to die.

*Control.* People are more afraid of events when they feel a lack of control over the situation. A good example is the fear to die in a plane crash relative to die in a car accident even though statistic shows that the risk of car accident is far greater than the risk of having a plane crash.

*Natural vs man-made.* Man-made risks evoke more risk than natural risks. Classically, nuclear energy source cause more concern than sun radiations that causes many skin cancers.

*Awareness.* Wide coverage by media, public health officials and NGOs will often create more alarm in the public. For example, creating a better understanding of the parent on the risks of children's exposure to cholera/dysentery outbreak via drinking of dirty water in school could enable them decide to take appropriate measures to mitigate the situation.

*Reversibility.* Risks perceived to have potentially irreversible harmful effects are less readily accepted and perceived to be posing with no permanent threat.

*Memory of risks.* A memorable incident, make a risk situation easier to evoke and imagine, and therefore seems greater.

*High risk to next generations.* Activities that pose a threat to future generations are most of the time judged to be more risky than those that threaten only the current exposed generations (5).

Individuals, communities as well as societies respond differently to hazardous situations, understanding these behavioural is critical to build appropriate risk communication strategies

and choose proper management strategies. In a study involving different groups like students, household women and scientific experts, participants were asked to rank activities or agents in order of their annual contributions to deaths (6). Participant's responses were distributed as a risk perception diagram: some of the known hazardous agents/situation were plotted on a X-Y risk space using two risk perception factors (dread and knowledge). It appeared that lay people tend not to accept risk that is both not observable (dread, global catastrophic, consequences fatal, unknown to those exposed, effect delayed, new risk, risks unknown to science) and uncontrollable (not equitable, high risk to future generations, not easily reduced, risk increasing, involuntary), while scientists tend not to accept observable (controllable or uncontrollable) risk. Promoting proper IEC on the potential hazards to which indigenous people are exposed to on day-to-day basis reduce exposure and risk.

## **Community health risk communication**

The essence of every communication is to ensure a change. Community communication for a deserving change is in characteristics otherwise called behavior. Therefore the perspective of communication herein discussed shall be towards change of behavior (lifestyle etc) to reduce exposure levels with consequential low risk to their health. Again the IHAF experience shall be widely incorporated. A categorical example here is HIV/AIDS exposure and food mycotoxins exposures. Routine IEC programs are indispensable for any desired change towards reduced exposure and consequential risk level.

To ensure an effective and a sustainable IEC for behavioral change in local communities, it is salient we get to the field for feasibility studies (surveys) during which open dialogues are made with indigents (bottom-to-top approach to policy making) and have good understanding of why they behave the way they actually do, for example is it related to culture, religion, and does it tamper with their human rights and or women's health and reproductive rights? And so on. Existing systems failed in that instead of predicting and preventing situations they rather wait for situations to occur for them to react. For example, access to IEC on HIV/AIDS is mostly to victims when it is too late, thus untimely access to information and education. IEC is supposed to be accessed by all (victims and healthy normals) as soon as possible.

Motivating households and communities to reduce (and where possible prevent) exposure to hazards is not an easy task. This requires good communication skills behaving and making self look like them for them to understand your language in addition to good educators and right information (illustrations, plays, dramas etc) for the right audience (local communities).

Getting households and the entire community participate in a united action to reduce exposure levels requires sustained communication interventions guided by well-planned and locally appropriate communication strategies particularly proper IEC; Communication for Behavior Change (CBC) approaches and Communication for Social Change (CSC).

## **Information, education and communication**

The IEC is broadly defined as providing knowledge to enable individuals, families, groups, organizations and communities to play active roles in achieving, protecting and sustaining their own health. Contents of IEC and methods of deliveries by IHAF's experiences vary across urban cities to rural communities. Many especially administrators and some civil society actors (NGOs or CSOs) have often misled communities as a result of not being able to distinguish their urban from rural audience. They failed to note that whatever one says or does for

communities depends on how the audience perceives the message. Their later actions or behaviors shall be influenced by how they understand your message. As a result, meanwhile a bulk of rural communities do not have access to IEC on high-risk activities in their day-to-day life, the few that have access do so late i.e. when they are already victims (and as individuals), worsen by the fact that healthy normals (HN) do not have access, in addition to the poor sensitization with inadequate understanding for proper self, household and community preventive measures such as behavioral changes amongst others.

## **Communication for behavioral change**

Similarly, the Communication for Behavioral Change (CBC) incorporates the basic components of the IEC. In addition, CBC begins with identifying the key behavior(s) as purported by individual(s) and or by group(s). Thereafter a multi-approaches (multi-interventions) which goes beyond cognitive-based and knowledge transfer are employed.

Basically, CBC is the process of working with individuals, households and communities towards developing communication strategies to promote positive behaviors which are appropriate to their settings as well as providing a supportive environment which will enable people to initiate and sustain positive behaviors.

It is vital to note that behavior is not only a matter of having information and making a personal choice. Behavior change also requires a supportive environment provided by the community/society in which you live, thus influenced by the process of development; access to health services/information; in addition to peer-, community or societal influences on the individual(s).

Prior to developing a CBC intervention, it is important to be clear about exactly whose behavior is to be influenced and which aspect of their behavior should be the focus for change. Communities are made up of different groups with different risk and vulnerability factors. Even within the same broad group, there may be subgroups with distinct characteristics. Different target groups will require different approaches. Therefore, when making decisions about which target groups and which factors to address, it is necessary to consider answering the following questions:

1. which target groups are most vulnerable;
2. which risk/vulnerability factors are most important;
3. which factors may be related to the impact of conflict and displacement;
4. which target groups and risk/vulnerability factors the community wants to address;
5. what could be motivators for behaviour change;
6. what could be barriers to behaviour change;
7. what type of messages will be meaningful to each target group;
8. which communication media would best reach the target group;
9. which services/resources are accessible to the target group;
10. Which target groups and risk/vulnerability factors are feasible in terms of expertise, resources and time (7).

A successful CBC program requires careful research and thorough pre-testing of communication materials. It is important not to underestimate the effort that is needed to carry out good quality behavioral research, which yields findings that are accurate and useful. The CBC methodology often needs improvement.

## **Communication for social change**

The CSC on the one hand is a more participatory approach to engaging communities that focuses more on the client-identified end actions in regard to the health intervention.

## Some recommendations for communication at the community level

The integrated approach adopted by the Integrated Health for All Foundation (IHAF) for Information, Education and Communication for Social and Behavioral Change (IECSBC) is a strategic merge of IEC, CBC and CSC (Table 1) (9). We highly recommend IECSBC for sustainable community communication aiming at reducing probabilities of occurrences of high risk with drastic consequences. This is fascinating considering it combines both the delivery of messages and other behavioral interventions and opportunities for dialogue, shared learning and consensus-building to produce results in a participatory or democratic manner.

**Table 1. IECSBC activities guide for field workers or mobilizes**

Steps	Key question	Outcome
<b>1 Identifying behaviors</b>	<ul style="list-style-type: none"> <li>• Are we addressing single or multiple behaviors?</li> <li>• How do we break down the issue into its component behaviors?</li> <li>• How do multiple behaviors relate or group?</li> <li>• Who do we want to undertake the behavior?</li> <li>• What is the desired and current behavior?</li> <li>• Does the behavior involve people starting, stopping, maintaining or preventing?</li> </ul>	<ul style="list-style-type: none"> <li>• Agreed target behavior</li> </ul>
<b>2 Understanding the influences by audience</b>	<p><b>Personal</b></p> <ul style="list-style-type: none"> <li>• What are the attitudes, values and beliefs of the target audience?</li> <li>• Is there a gap between attitudes and behavior?</li> <li>• Are people aware of the need to undertake the behavior? Is the requirement known to them?</li> <li>• Do they have the knowledge to undertake the behavior?</li> <li>• Is the behavior habitual or one-off?</li> <li>• Are people confident about undertaking the behavior?</li> <li>• If people do undertake the behavior, will the outcome be beneficial to them?</li> <li>• What emotions are involved in the current and desired behaviors?</li> <li>• What biases/heuristics might be at play?</li> </ul> <p><b>Social</b></p> <ul style="list-style-type: none"> <li>• Is the behavior in line with or against social norms?</li> <li>• Is peer pressure likely to be an influence?</li> <li>• Who will influence them, and how strong will their influence be?</li> </ul> <p><b>Environnemental</b></p> <ul style="list-style-type: none"> <li>• What factors influence them at the local and wider environmental level (access, price, opportunity, services and proximity)?</li> <li>• How do factors differ across audiences how does their importance vary across different audience?</li> </ul>	<ul style="list-style-type: none"> <li>• Detailed understanding of all influencing factors</li> </ul>
<b>3 Developing a practical model of influence behavior</b>	<ul style="list-style-type: none"> <li>• How do we prioritize the factors identified at step 2?</li> <li>• How do these factors influence current and desired behaviors?</li> <li>• What is the relative importance of the factors?</li> <li>• Do we have data to measure the factors?</li> <li>• Can we build a data-driven model?</li> <li>• If we can't, what are the pragmatic hypotheses we can work with and test?</li> <li>• What are our early hypotheses about how behavior might change?</li> <li>• What are our early hypotheses about the role that communications might play?</li> </ul>	<ul style="list-style-type: none"> <li>• Model of key influencing factors.</li> <li>• Understanding and/or measurement of how the factors work together and their importance.</li> <li>• Initial hypothesis about role of communications</li> </ul>

*to be continued*



continues

Steps	Key question	Outcome
<b>4 Building a marketing framework</b>	<ul style="list-style-type: none"> <li>• What factors will marketing/interventions need to target?</li> <li>• Where will communications play a role? What factors will they affect, and how? Will they play a leading or supporting role?</li> <li>• What are the communication objectives?</li> <li>• What are our top-line evaluation metrics for these communication objectives?</li> </ul>	<ul style="list-style-type: none"> <li>• An understanding of the role communications and the factors they are designed to influence</li> <li>• An agreed set of communications objectives.</li> <li>• How communications fit into the wider picture.</li> <li>• Top-line metrics for setting and evaluating key performance indicator.</li> </ul>
<b>5 Developing a communication model</b>	<ul style="list-style-type: none"> <li>• Does everyone involved understand the role communications can play and the factors they are aiming to influence?</li> <li>• How do we expect communications to influence people's behavior over time?</li> <li>• What are the key triggers and barriers at each stage of our change journey?</li> <li>• How will communications influence these?</li> <li>• Where do communications fit in with the marketing framework?</li> <li>• How do we evaluate each stage of change journey?</li> <li>• How can we use our learning to adapt our applied model?</li> <li>• How can we used our learning to adapt our hypothesis?</li> </ul>	<ul style="list-style-type: none"> <li>• A communications model</li> <li>• An understanding of whom communications are targeting and where communications fit into the overall pictures.</li> <li>• An evaluation and matrix</li> </ul>

This integrated approach does not merely provide individuals, households or families and communities with information and building their capacities but increase and promote good communication strategies to promote positive behaviors which are appropriate to their settings. This approach encourages operation help that people do themselves for sustainability.

We concluded that it is better to teach the indigenous people how to fish rather than providing them fish, because we shall not always be there to provide fish when they need it. Proper feasibility studies and surveys and research in addition to proper planning, forms a reliable basement for an effective communication campaign. This is not to be doubted considering that it will enable you better understand and appreciate the problems/ needs of the population and probably prioritize them in a participatory manner.

Findings of such studies are the basis of the contents of issues on which to raise awareness and, ultimately, changing attitudes and behavior. In other words:

- (i) determine the problems/needs and desires of the community/audience
- (ii) deliver information, services and products that offer real benefits
- (iii) monitor and evaluate (social/behavioral) changes and ensure sustainability.

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**PART B**  
**African scenarios:**  
**case studies**



# POTABLE WATER SUPPLY AND ENVIRONMENTAL POLLUTION IN SOUTH-SOUTH NIGERIA: A BIRD'S EYE-VIEW

Orish Ebere Orisakwe (a), Chiara Frazzoli (b)

(a) Faculty of Pharmacy, University of Port Harcourt, Nigeria

(b) Department of Veterinary Public Health and Food Safety, Istituto Superiore di Sanità, Italy

## Introduction

The south-south Nigeria also known as the Niger Delta is located in Atlantic coast of southern Nigeria where River Niger divides into numerous tributaries. The area is the second largest delta in the world spanning a coastline of about 450 kilometers foreclosing at the Imo River. It is the largest wetland in Africa, spanning over 20,000 square kilometers and among the three largest in the world. It is estimated that about 2,400 sq km of the area consist of rivers, creeks and estuaries and while stagnant swamp covers about 8,600 sq km. Its mangrove swamp of 1,900 sq km is the largest in Africa. The area falls within the tropical rain forest zone of Nigeria. The ecosystem of the area is highly diverse and supportive of several species of terrestrial and aquatic flora, fauna and human life. The region is divided into four zones namely coastal inland zone, mangrove swamp zone, freshwater zone and lowland rain forest zone. Researchers have carried out studies on engineering properties of soil in the Niger Delta as to determine parameters for borehole development and constructing engineering structures based on grain size distribution analysis. The dominant freshwater aquifer is found in the Benin formation. Though there is shallow aquifer, the thickness of Benin formation generally exceeds 2000 m with high consolidation at deep levels (1). Accessible fresh water could occur in the first 100-200 m (2). Water levels can be located at less than 1 m near the coast to more than 10 m further inland (3). The whole of delta region receives more than 5000 mm of rainfall every year (4). Evapo-transpiration is estimated at over 1000 m annually, so there is enough rainfall to recharge surface and groundwater system, although organic matter and clay matrix that consolidate the soil may interfere with infiltration and seepage into the aquifer (5).

## Water quality

The evaluation of the microbiological quality of drinking water aims to protect consumers from illness due to consumption of water that may contain pathogens such as bacteria, viruses and protozoa, and thus to prevent drinking-water related illness outbreaks. This has been, and still is nowadays an important challenge. For the past century, this evaluation has been performed through the analysis in finished drinking water of faecal pollution indicators, which are expected to predict the potential presence of pathogenic microorganisms in the water.

Excessive rainfall has been an important contributor to historical waterborne disease outbreaks (6-11). In fact, most of the bacteriological parameters (heterotrophic bacteria, *E. coli*, total coliforms, faecal streptococci, and *Clostridium perfringens* counts) increased considerably during extreme runoff events as do the concentrations of *Giardia* and *Cryptosporidium* (8-10).

The increasing demand for potable water to supply domestic and commercial needs has necessitated the growing use of groundwater along with other sources. The total groundwater withdrawal in the Niger Delta is largely unknown. Although groundwater obtained from aquifers or wells protected from bacterial pollution by impervious strata do not need disinfection, this protection is frequently not available. Ground water is an important natural resource. The majority of the Nigerian population including the Niger Delta depends on groundwater for drinking. Thus, preservation of clean groundwater is of utmost importance. Although there are numerous sources of contaminants, they are all related to three potential roots: namely, water soluble products that are stored or spread on the land surface, substances that are deposited or stored in the ground above water table and material that is stored, disposed of or even extracted from below the water table. The problem with groundwater contamination is magnified by the fact that ground water flows extremely slowly (about 1-10 ft per day). Thus in comparison to surface water, there is little mixing and dispersal of contaminants. The link between the contaminants of ground water and any specific disease cannot be easily established.

Physical and sanitary quality of hand-dug well water from oil-producing area of Nigeria has been studied (12) and chemical-physical parameters (dissolved solids, dissolved oxygen, conductivity) were found within WHO limits. The pH is slightly acidic ( $6.04 \pm 0.66$  in dry season;  $6.43 \pm 0.62$  in wet season) and may be attributed to emissions from gas flaring and petroleum refining activities, which is common in the area. Compared to WHO limits (13), the higher temperature reflects the tropical environment. With the exception of temperature and pH the values recorded for the physical parameters were within WHO limits, the season notwithstanding. Although these parameters decline during the wet season with the exception of pH and temperature, only that of conductivity and static water level values are significant.

The coliform counts vary from one well source to another in both seasons. The total coliform counts are generally high indicating poor sanitary handling and/or environmental conditions of many of the wells because they are not specific faecal matter indicators. By WHO guidelines (14), no faecal coliform should be detected in any 100 mL of water. The public health implication of this is obvious because faecal coliforms are associated with faecal matter, which may contain pathogens. The dry and wet seasonal differences for total coliform counts are on the average not significant ( $\log_{10}$  MPN/100 mL:  $4.22 \pm 1.50$  vs  $2.15 \pm 0.65$ ;  $p > 0.05$ ). However, wet season counts are significantly higher with regard to faecal coliforms ( $\log_{10}$  MPN/100 mL:  $0.48 \pm 1.12$  vs  $1.15 \pm 0.96$ ,  $p < 0.05$ ). Although the differences are not significant, total coliform tend to decrease during the wet season (12). The significant increase in faecal coliform counts, which truly warn against the entry of pathogens, is in contrast to the decreasing trend. However, significant increase in faecal coliform counts occurred during the wet season in wells close to septic tanks (12). This was not the case with those far away. This suggests that the septic tanks may have been the source of the faecal coliforms, and that their entry may be due to increased seepages caused by the heavy tropical rainfall. It also suggests that some of the septic tanks may be failing with respect to confining the human wastes.

On the other hand the fact that precipitation did not increase total coliform counts irrespective of well features, use or location suggests that their route to the well may include other sources. In the course of sample collections, authors found that the buckets used for collecting water were often left on the soil, corridor floors, kitchens or hung beside the well (12). In addition children were mainly responsible for drawing water.

Mechanically operated wells were rare and often not functioning due to lack of maintenance. The unsanitary habits of the users predispose the wells to contamination especially by non-faecal coliforms and also accounts for the variations of coliform bacterial counts. In the course of discussion with the users of well water, Ejechi's group ascertained that the frequency of usage of well water decreased during the wet season because of the use of harvested rainwater.

It is logical to associate the decline of non-faecal coliform counts during the wet season to reduced well water use. The faecal coliforms are of human origin and they can be found in septic tanks whereas the non-faecal coliforms can come from soil, domestic wastes and decaying organic matter, which can contaminate buckets as noted earlier. A reduced use of buckets during the wet season may then reduce incidence of well contamination whereas septic tank seepages increase bringing more faecal coliforms.

Results of the above study showed that the well features, location or use did not significantly increase the ingress of the total coliform bacteria in any of the seasons. Rather the counts tended to decrease during the wet season. With respect to faecal coliforms, significant increases occurred only in wells close to septic tanks during the wet season. The casing was expected to limit seepages from the surrounding soil while single-family use of wells was to reduce contamination because of less frequent use. Seepages from septic tanks were expected to decline with distance from the wells. Authors therefore buttress the suggestion that the unsanitary habits of the users are major sources of the indicator bacteria (12). Contamination of the water supplies through the failure of septic tanks has also been confirmed by the presence of fecal streptococci in the water samples. This group of organisms is consistently present in the faeces of all warm-blooded animals and in the environment associated with animal discharges.

Though spring water is considered to be aesthetically acceptable for domestic use, total absence of toilet facilities, presence of poorly designed pit latrines, poor wastewater management, poor solid waste management as well as poor and inadequate spring protection, may lead to contamination of water from the springs with pathogenic bacteria. Generally, people drink substandard waters in the Niger Delta, because only few water samples may meet the standards established by health authorities. The coliform bacteria are present in over 80% of the water supply sources, indicating that these supplies are polluted, but it does not necessarily prove that the contamination was from a fecal source. The nonfecal coliform bacteria can survive for a long time out of their natural habitat.

According to the American Society for Microbiology many serious health problems could be eliminated if more countries adopted water quality practices, including the simple steps of source water protection and disinfection to ensure safe water supplies. Therefore, the control of microbial pathogens must be carried out by the use of a multi-barrier approach, including source protection, proper treatment and disinfection, and optimal distribution maintenance (15, 16).

Waterborne pathogens could be spread within the freshwater after a contamination by animal or human waste due to heavy rainfall discharge in combined sewer systems (CSS) (17, 18). When the flow exceeds the CSS capacity, the sewers overflow directly into surface water body (17). Pednekar *et al.* (19) have studied coliform load in a tidal embayment and shown that storm-water coming from the surrounding watershed is a primary source of coliform. Moreover, higher water temperatures will probably lead to a pathogen survival increase in the environment, although there is still no clear evidence (20). Floods often led to a contamination of groundwater and additional disease outbreaks (18, 21). Flooding is a common feature of the south-south area of Nigeria and the water bodies are inadvertently polluted.

## Nitrate and nitrite

In 2008 nitrate and nitrite in different water sources (surface water, shallow well water and borehole water) in the market and industrialized areas of Warri in Niger Delta area of Nigeria were investigated (22). The results (mg/mL) showed the range of nitrate and nitrite in the industrialized areas was as follows: surface water (nitrate 0.40-4.28; nitrite 0.03-1.34), shallow well (nitrate 1.12-1.48; nitrite 0.08-0.32), borehole (nitrate 0.18-2.63; nitrite 0.03-0.08) while

that for market area were: surface water (nitrate 0.22-8.36; nitrite 0.16-1.12), shallow well (nitrate 2.17-2.40; nitrite 0.60-1.14), borehole (nitrate 1.18-1.40; nitrite 0.02-0.08).

High nitrate and nitrites levels in water is an indication of the environmental burden of nitrate from the decaying matter and refuse dumps which is a common feature of most cities in the developing nations like Nigeria (23). This may be the plausible explanation for the higher nitrate levels from the market area seen. The pollution load of nitrate and nitrites from household and market wastes into water resources in Nigeria constitute an important consideration in determining environmental exposure to chemicals. Also the high level of nitrate recorded in rainwater samples in other parts of the Niger Delta can be attributed to the natural process of photochemical oxidation of nitrogen to give oxides of nitrogen during lightning and thunderstorms, which becomes soluble during rainfall. Similar observations have been made for the concentration of nitrate in harvested rainwater in gas-flared area.

In Nigeria, borehole water supply is regarded as safe as most middle class of socio-economic strata rely on this source of water supply. But it may not be safe as it was thought to be (24); this is compounded by the fact that adequate public and safe drinking water supply is almost non-existent in Nigeria. A worst scenario is seen in the Warri study area where the only source of water supply to the poor inhabitant who has borne the scourge of several years of oil pollution and gas flaring is surface and shallow well water, whereas there is no significant difference in pollution profile of the two, since most shallow well water are recharged by surface water and rainfall. This may be responsible for serious health problems in the Niger Delta creeks.

### **Heavy metal pollution**

River bodies and hand dug wells in the Niger Delta area of Nigeria have values for Lead, Mercury, Nickel, Vanadium and Zinc of water samples collected from the hand dug wells that are within WHO standards for safe drinking water (25).

In 1997 Aremu and coworkers reported high levels of Fe, Ni, and Pb in the groundwater of Warri, Niger Delta, Nigeria (26). Surveys on potable water supply in Warri, Niger Delta, Nigeria have been also conducted to determine the heavy metal contamination profiles of some rivers, shallow wells and boreholes (27, 28). Ekpan River was found to have 1.2 mg/L of Cadmium, 1.0 mg/L of Chromium, 1.20 mg/L of Lead and 2.0 mg/L of Manganese.

### **Poly-aromatic and straight chain hydrocarbons pollution**

Poly-Aromatic Hydrocarbons (PAHs) are among the most potent carcinogens known to exist, producing toxic effects in some wildlife organisms through single exposures to microgram concentrations (29). Based on WHO qualitative classification of PAHs carcinogenicity (30), we can divide the sixteen priority PAHs into two categories: the first category contains PAHs having sufficient or limited evidence for carcinogenicity, namely benzo(a)pyrene, benz[a]anthracene, chrysene, dibenz[a,h]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, indeno[1,2,3-cd]pyrene and benzo[g,h,i]perylene. The second category includes PAHs with insufficient or no evidence for carcinogenicity, namely naphthalene, fluorene, anthracene, phenanthrene fluoranthene, pyrene, acenaphthylene and acenaphthene. Of all these, only acenaphthene, 1,2-benzoanthracene, benzo[b]fluoranthene, benzo[g,h,i]perylene, dibenzo[a,h]anthracene and chrysene were found in Anieze river, while chrysene and fluorene were found in Orash river (Rivers State) and only dibenzo[a,h]anthracene was found in Ifie-Kporo creek (Delta State); none was found in other surface water bodies (31).



It has been shown that microorganism indigenous to soil, groundwater and marine ecosystems degrade a wide range of compounds such as aromatic and aliphatic hydrocarbons, chlorinated solvents and pesticides released into natural environment (32), since empirical evidence that aromatic and aliphatic hydrocarbons exist in the Niger-Delta marine ecosystem due to extensive crude oil and gas exploitation, fire explosions, leachets from decomposing refuse and industrial effluents (33-36). Nduka (31) reported that PAHs were found in Anieze river, Orash rivers and Ifie-kporo creek while different carbon chain length of straight chain (aliphatic) hydrocarbon were found in different concentrations in the samples analyzed. Fewer or no counts of *achromobacter* and *aspergillus* (PAHs degraders) and proteus (straight chain hydrocarbon degraders) were found in most water samples while *bacillus* and *Pseudomonas* spp., both PAHs and straight chain hydrocarbon degraders (37) were found in higher counts and in almost all the water samples (31).

## Rainwater and acid rain in the Niger Delta

According to Efe (38), rainwater samples harvested from the different roofing sheets in some parts of Delta State were acidic with the exception of open surface and show high level of unsatisfactory concentration. Most communities in the Niger Delta believe that gas flaring cause acid rain that results in the corrosion of the metal sheets used for roofing which is actually used in harvesting rain water. Yet, oil company officials hold onto the argument that the Nigerian gas is a low-sulphur content gas, there is no possibility of causing acid rain as a result of gas flaring. Current researches emerging from the Niger Delta confirm the presence of both acidic water and acid rain. In view of the high dependence on rain water there is need to assess its suitability for drinking, cooking and other domestic uses.

Apart from acidic precipitation and its negative impact, acid rain precursor gases ( $\text{NO}_2$  and  $\text{SO}_2$ ) are part of six common outdoor pollutants. Nitrogen dioxide ( $\text{NO}_2$ ) poses a health threat itself as well as playing a major role in the formation of the photochemical pollutant ozone. Research has shown that animals exposed to  $\text{NO}_2$  have diminished resistance to both bacterial and viral infection, while children exposed to high indoor levels of  $\text{NO}_2$  may become more susceptible to critical infections of the lower respiratory tract, bronchial tubes, and lungs, and may develop bronchitis and chest cough with phlegm. Sulfur dioxide ( $\text{SO}_2$ ) is a temporary irritant, although studies have shown that increased levels of  $\text{SO}_2$  in conjunction with particulate matter may trigger small, but measurable, temporary deficits in lung function.

Increased acidity of rain indicating high  $\text{NO}_2$  and  $\text{SO}_2$  emissions may predispose the natives to spontaneous abortion, ectopic pregnancy, malignant lymphomas or soft tissues sarcomas (27).

Researchers have therefore suggested that the rainwater from these rural communities should be harvested, stored for human consumption and for other uses by the inhabitants. But treatment is needed in terms of their pH, TSS, Fe and colour. Thus, rainwater from these sources should be purified before consumption. After an attempt to treat the rainwater samples using the fixed-bed filled with bone char in terms of removal efficiency of pollutants in raw harvested rainwater, it was found that the analyses of the effluent showed a good reduction of turbidity from 19.4 to 2.6 NTU (39).

The biodiversity of the Niger Delta is under serious threat; the worst affected are the interwoven water bodies. There have been reduced fish catches; plankton, freshwater shrimp, snails, and mussels on which fish feed are most affected by acidification. Fish such as minnows, salmon, and roach are equally threatened. Roe and fry (eggs and young) of the fish are the worst affected. The acidification can also cause deformity of young fish and can prevent eggs from hatching properly, which leads to fish-eating birds and animals also being affected.

In the Niger Delta region, human health problems are reported to be linked to acid rain, including skin lesions, and even cancers, as well as gastric and intestinal lesions due to the consumption of acidic water. Moreover, acid rain can increase the environmental leaching of pollutants such as heavy metals (40). Nigerians depend heavily on rainwater for drinking, cooking, laundry, and other domestic uses. It is hoped that a potable water supply will become a high-priority issue for the government as water treatment is rarely carried out at the household level.

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# SOLID WASTE AND WASTE MANAGEMENT ISSUES IN SUB-SAHARAN AFRICA: A FOCUS ON NIGERIA

Orish Ebere Orisakwe (a), Chiara Frazzoli (b)

(a) Faculty of Pharmacy, University of Port Harcourt, Nigeria

(b) Department of Veterinary Public Health and Food Safety, Istituto Superiore di Sanità, Italy

## Introduction

According to the 1996 *Global Report on Human Settlements*, between one-third and one-half of the solid wastes generated within most cities in low and middle-income countries are not collected. They usually end up as illegal dumps on streets, open spaces and waste land. The proportion of solid wastes collected and disposed of is less than 25% in Dar es Salaam (Tanzania) (1). It is believed that in the poorest communities (many of which are in sub-Saharan Africa), 80 to 90 per cent of wastes generated are not collected for safe disposal. Even in countries where city authorities provide waste services, these are often spatially concentrated, leaving some parts of the city unserved.

High heaps of refuse dumps which emit repulsive odor resulting from decomposing organic and agricultural waste are common features of many cities in Nigeria. These act as aesthetic pollutants and as sink or breeding ground of microbes. Typical refuse dumps in Nigeria comprise of all and sundry. Physical, chemical and biological factors such as temperature, rainfall, humidity and microbes combine to degrade them (2).

E-waste is a popular, informal name for discarded and End-Of Life (EOL) Electrical and Electronic Equipment (EEE) comprising information and communication technology equipment, home electrical appliances, audio & video products, and all of their peripherals. However, according to UNEP (3), “ewaste is a generic term encompassing various forms of EEE that are old, end-of life electronic appliances and have ceased to be of any value to their owners”. This is by far the reasonably best definition of e-waste as of now. A practical definition of e-waste is “any electrically powered appliance that fails to satisfy the current owner for its originally intended purpose”. In accordance to the European Union WEEE Directive, the terms WEEE (Waste Electrical and Electronics Equipment) and “e-waste” (electronic waste) are used synonymously.

In the attempt to advance in ICT and bridge the ‘digital divide’ by launching citizenries to the information and technology age, most developing countries during the past decade have been relying on second-hand or refurbished EEEs, from developed countries. High level of trans-boundary low-cost movement of second-hand/scrap electronic equipments is dumped, most of which are imported without confirmatory testing for functionality. As a result, large quantities of e-waste have been handled in developing countries, where processed materials comes mixed with other categories of EEEs, including obsolete computers as donations by dubious foreign firms. This is particularly worrying in developing nations of Africa, which have become one of the world’s latest destinations for obsolete EEE.

Despite the regulations to prevent e-waste from being dumped, a hidden flow of end-of-life electronics is threatening to drown West Africa: every month, hundreds of tons of obsolete computers, televisions and other household consumer electronics are arriving at ports in Nigeria and Ghana. From here, the second-hand electronics are distributed via local networks of dealers throughout the country and piles of discarded television sets, PCs and other electronics

equipment are put out for sale around Lagos and Accra. Local traders report that to get a shipping container with a few working computers they must accept broken junk in the same container. The broken junk and eventually even the working computers inevitably are dumped in Nigeria and Ghana, where there is no infrastructure to safely recycle toxic e-waste. The modes of disposal, including simply dumping into landfills or burning in smelters, expose humans and the environment to a highly toxic cocktail of chemicals.

In 2007 the Federal Government of Nigeria disclosed that the legal and illegal importation of second-hand EEEs into the country is creating serious human and environmental problems and threats to environmental sustainability. In fact, illegal e-waste material is abandoned at riverbanks in dumping sites such as largest ports in Lagos, where it is manually disassembled, repaired and marketed. In Nigeria a preliminary survey of e-waste found about 200 tonnes of e-waste. The result of the research in Nigeria conducted in 2005 by the Basel action network in conjunction with the Basel convention regional coordinating center in Ibadan revealed that about 400,000 used computers enter Africa by 500 shipping containers every month through Lagos alone. Although many of these machines can be repaired and resold, up to 75% of the electronics shipped to Africa is useless junk and ends up on dumpsite fires (4, 5). Media releases report that Ghana also is increasingly becoming a dumping ground for waste from Europe and the USA.

Challenges faced in e-waste management are not only the consequence of the growing quantities of waste, but also of the complexity of e-waste. E-waste is one of the most complex waste streams because of the wide variety of products ranging from mechanical devices to highly integrated systems and rapidly changing product design. Electronic products are an integration of numerous modern technologies and are composed of many different materials and components (6).

As electronics increasingly become part of the throw away culture in many developed countries, amounts of e-waste have dramatically increased while solutions have often lagged far behind. Even in the European Union that has tighter regulation, 75% of e-waste is unaccounted for. Of the estimated 8.7 million tonnes of e-waste created annually in the EU a massive 6.6 million tonnes of e-waste is not recycled.

Literature data from some countries have been documented (7), where the widespread and severe contamination of all Chinese environmental compartments is shown. Unfortunately the weight and size of this scourge in many African countries which have become the major wastelands is largely unknown.

WEEE is a complex mixture of Ag, Au, Pd, and Pt as precious metals; Cu, Al, Ni, Sn, Zn, and Fe as base metals; Hg, Be, Pb, Cd, Cr(VI), As, Sb, and Bi as metals of concern; halogens and combustibles (plastics/flame retardants) (8), many of which are toxic. Besides toxic materials, e-waste also contains considerable quantities of valuables in the form of precious metals. Whereas this statement may be true for WEEE exported to some Asian countries, it is very doubtful if same apply to WEEE exported to coastal countries of sub-Saharan Africa like Nigeria and Ghana especially.

The toxicity is due in part to lead, mercury, cadmium, and a host of other substances. For instance, lead comprises approximately 20% of each cathode ray tube (CRT); about 4 to 8 pounds per unit (9).

Due to poor environmental standards and working conditions in sub-Saharan Africa countries, ewaste has continued to be exported to these countries for processing contravening the Basel Convention. Due to the hazards involved, disposing and recycling WEEE has serious legal and environmental implications. When computer waste is landfilled or incinerated, it poses a significant threat to the environment. Landfills leach toxicants into the groundwater and uncontrolled open burning emits toxic air pollutants including dioxins. Likewise, the recycling

of computers has serious occupational and environmental implications, particularly when the recycling industry is often marginally profitable at best and often cannot afford to take the necessary precautions to protect the environment and worker's health. Some studies so far have revealed that significant health and environment problems were associated with the activities viz., Surface Heating of Printed Wiring Board (PWB), cable burning (PVC and Cu), gold extractions (from pins and comb), and acid bath for PWB (10). For instance, Awka has been the site of increased human activities since it became a state capital in 1991: because refuse dumps have hitherto been a disregarded environmental menace in Nigeria, the metal levels in 5 dumpsites were found to exceed the limits set forth by the US Environmental Protection Agency (Table 1) (11, 12).

**Table 1. Soil contamination by chemical elements (mg/kg) in Awka, Nigeria**

Fe	Zn	Pb	Cu	Mn	As	Cr	Cd	Ni	Co	Na	Mg	K
40,500	235	1297	18	751	2300	10.0	6.20	55.0	264	3000	1050	480
38,980	567	1700	35	600	201	5.0	7.0	97.0	480	3100	1390	510
55,200	185	2467	ND	451	200	6.0	6.14	62.0	109	3401	1520	670
72,200	244	1543	ND	193	43.7	6.48	5.18	246	71.0	3561	1360	9.58
21,502	265	572	20	644	412	7.0	6.58	177	70	3020	1301	750
*62,000	*76	*13	*68	*1060	*1.8	*122	*0.16	*99	*29	*22,700	*27,640	*18,400

\*Abundance of the chemical elements on the earth's crust.

In a recent study in Nigeria (13) the mean Blood Lead Level (BLL) was found among children to be 8.9 mg/dL and the median value was 7.8 mg/dL. About 160 children (25% of study population) had a BLL greater than 10 mg/dL. BLLs in many western countries have progressively declined over the years. In Nigeria, however, high BLL have been documented not only in occupational cohorts but also in "unexposed" control subjects. The high BLL among controls casts doubts about how exposed these "unexposed control subjects" actually are (13).

Industrialization is considered vital to the nation's socio-economic development as well as to its political standing in the international community. Industry provides employment opportunities for a large proportion of the population in medium to highly developed economies. The characteristics and complexity of wastes discharged by industries vary according to the process technology, the size of the industry and the nature of the products.

Surface water and groundwater contamination, air pollution, solid waste dumps and general environmental degradation, including the loss of land and aquatic resources, are major environmental problems caused by industrialisation in Nigeria. Improper disposal of untreated industrial wastes has resulted in coloured, murky, odorous and unwholesome surface waters, fish kills and a loss of recreational amenities. A significant proportion of the population still relies on surface waters for drinking, washing, fishing and swimming. Industry also needs water of acceptable quality for processing.

## Environmental remediation and waste management programmes

The mountainous heaps of solid wastes that deface Nigerian cities and the continuous discharges of industrial contaminants into streams and rivers without treatment motivated the federal government of Nigeria to promulgate Decree 58 for the establishment of a Federal

Environmental Protection Agency (FEPA) on 30 December 1988 (14). A national policy on the environment was formed and the goals of the policy include: to secure for all Nigerians a quality of environment adequate for their health and well-being; to raise public awareness and promote understanding of the essential linkages between the environment and development; and to encourage individual and community participation in environmental protection and improvement efforts (15).

With respect to solid waste, the deterioration of the urban environment resulting from heaps of uncollected refuse in neighbourhoods and public places, coupled with the apparent inability of the city authorities to respond effectively to the challenge, necessitated the search for other options. Four broad types of private sector participation in solid waste management have been identified, namely: contracting, concessions, franchises and open competition (16).

Poor financing is characteristic of public waste services provision in Nigeria. According to a national profile of the Nigerian environment, the problem of solid waste disposal in the country's cities has become one of the most intractable environmental problems. The national profile observed that "[...] in many Nigerian cities, the volume of solid wastes has overwhelmed urban administrators' capacity to plan for their collection and disposal. Thus, it is not uncommon to find urban streets and roads practically blocked by solid wastes [...]" (17).

The national profile suggests that the annual per capita solid waste generated in Nigeria was 20 kilos in the nineties, which amounts to about 2 million tonnes a year if we use an approximate national population figure of 100 million in 1996.

Effective solid waste collection and disposal has remained a challenge to urban management in Nigeria. With no rapid improvement in public finances in sight, the involvement of the private sector in waste services is inescapable. Solid waste services in many Nigerian cities are inadequate (18) (Figure 1).



**Figure 1. Littered waste on motor way in Onitsha, South East Nigeria: attempts as shown in this photo are made to remove the wastes but how consistent are these efforts?**



Inadequate solid waste disposal affects the residential quality as well as the general environmental quality of Benin City. The absence of waste services can jeopardize other infrastructure services such as roads and stormwater drains (19) for example, by blocking stormwater channels and encouraging flash floods and flood pondages, which often occur in the city. This inadequate municipal waste service in Benin is typical not only of Nigerian cities (20-22), but also of many cities in Africa, South America and South-East Asia (23). For instance, inadequate waste disposal conditions in the suburban areas of Benin are largely typical of metropolitan Manila, where the relevant authorities do little to cater for poor and spontaneous suburban settlements (24, 25).

A number of factors are responsible for the poor waste service conditions in the city, ranging from poor financing to inadequate institutional arrangements. The Environmental Sanitation Unit lacks the personnel, resources and equipment to cover all parts of the cities in Nigeria. As a result, the unit's services are restricted to the core (old city) and some parts of the intermediate zone.

There is no policy on composting, unlike in some other countries where it constitutes an important waste management tool. In Nigeria, some people dump commingled solid waste on their farms for soil enrichment, being ignorant of the possible contamination of their crops and water sources (26). Excessive copper in natural water sources (3000 µg/L) results in acute gastrointestinal disturbances with vomiting, epigastric burns, and diarrhea (27). Waterborne diseases, kidney damage, and cancer may be caused by drinking water contaminated by cadmium in excess of 10-15 µg/day (27). Lead concentrations in natural waters are low (up to 2 µg/L) but may be increased by discharges from industries and solid waste dumps. Lead in excess of 30 µg/100 mL may affect the hematopoietic, the central nervous, and the reproductive systems (27). In parts of Lagos some of the waters showed highly acidic pH (as low as 3.4): this condition accelerates the dissolution of heavy metals (28).

Land-filling, which involves the burial of waste in pits by bulldozers, is the main method of waste disposal, and the public authorities should make the provision of disposal sites a priority in solid waste management in cities.

There is no recycling program. Only a limited amount of recyclables such as cans, plastics, bottles, and papers are stored in homes and later sold to scavengers and waste vendors. The activities of scavengers can have a great impact on the economy and waste management (29) if the scavengers are properly organized, enlightened, and provided with the necessary economic and institutional support. At present, however, their contributions are limited by the absence of government policy to encourage reuse and recycling.

There are two sanitary landfills in the whole country. Solid waste is mainly disposed of on controlled landfills, open dumps, and waterbodies. Uncontrolled burning of dumps as well as burning of refuse from homes such as secret documents, rags, and tires are common. Different types of wastes including hazardous wastes are dumped together without any real awareness as to their compatibility with one another. Unlike in advanced countries, incineration is not used as a waste reduction or disposal technique.

The proposed biological remediation of these programmes covers microbial treatment and the direct use of other natural resources to combat degradation by involving the people in a participatory development approach. Essentially two plants, *i.e.* kenaf (*Hibiscus cannabinus*) and vetiver (*Vetivera zizanioides*), are being used in the project.

In spite of the formulation of FEPA and a national environmental policy, the environment has not been adequately protected. Interest is mainly on aesthetics, which is rarely achieved. Waste collection is irregular and restricted to the major cities. Improperly sited open dumps deface several cities, thereby endangering public health by encouraging the spread of odors and diseases, uncontrolled recycling of contaminated goods, and pollution of water sources (30, 31).

The poor state of waste management is attributable to an inadequately formulated and poorly implemented environmental policy, among other factors. Besides, waste management is a multidimensional problem that has been aggravated in Nigeria by rapid urbanization and population growth rate. Therefore, the state environmental agencies are continuously faced with an increasing amount of solid wastes to handle. Neglect of the economic, social, psychological, political and cultural life of Nigerians in the formulation and implementation of programs has also contributed immensely to unsuccessful waste management.

Industrialization remains the yearning of the Africa's teeming population for more energy, foods, goods and services. However, pollution inevitably arises therefrom. Although the economic benefits of industrialization are enormous and incontestable, there is a need to make industrialization compatible with reasonably healthy environment in which contaminant levels are minimized.

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## **FOOD SECURITY IN CAMEROON AND NIGERIA: ANIMAL PRODUCTION AND ANIMAL HEALTH**

Giorgio Antonio Presicce

*Agenzia Regionale per lo Sviluppo e l'Innovazione dell'Agricoltura del Lazio (ARSIAL), Italy*

### **Concept of food security/insecurity**

Food security or probably better posed as “food insecurity” is caused by natural, economic and socio-cultural factors. These factors are so interlinked and mutually reinforce each other that, resolving one does not revert the problem, thus there is the need for a multidisciplinary approach that will take into consideration all the causal factors. Many definitions of food security have been developed. However, there are some, which have been more widely used than others. This is the case with the one developed by the World Bank in 1986. Base on this definition, food security implies “access by all people at all times to enough food for an active, healthy life” (1). From the nutrition point of view, the food security of a country, region or household can be seen as its ability to meet up with its “target consumption levels on a yearly basis”.

In 1974, the Food and Agricultural Organization (FAO) of the United Nations held the First World Conference on food security (2). During this conference it was agreed that everyone has the “inalienable right to be free from hunger and malnutrition for the development of their physical and mental faculties”. In 1996, another World Food Summit (WFS) of heads of states of FAO member countries was convened in Rome-Italy. The driving forces behind the convening of this conference were, first, to reaffirm their stand on the fact that each citizen has the “inalienable right to be free from hunger and malnutrition” and achieve food security for all. In addition and as second consideration, the number of hungry and undernourished people across the globe kept on increasing despite the commitments taken by the various heads of states to achieve food security for all (3). The main outcome of this summit was the adoption of the Rome Declaration on World Food Security and the World Food Summit Plan of Action. The prime objective of this plan was to reduce the number of hungry and undernourished people in the world from 800 to 400 millions by the year 2015. For the past years, food insecurity has caused high morbidity and mortality of children as well as adults.

The current figure for undernourished and hungry people in the world stands at 800 millions. There are positive steps being taken in some countries with regards to the implementation of this plan of action such as in Asia and Latin America. On the contrary, in Africa, especially sub-Saharan Africa, the situation seems to be aggravating. FAO estimates predict that if no progress is made, about 680 M people will still remain hungry by the year 2010, with more than 250 M of them being in sub-Saharan Africa (4, 5).

The Sahel region is one of the hunger hotspot in sub-Saharan Africa. The peak of food insecurity in this region occurred in 1973-1974 (6). Empirical evidence has shown that by the year 2020, food insecurity will be reduced in all developing countries except for sub-Saharan Africa. Although total cereal production will increase in sub-Saharan Africa, demand will exceed supply in the future as a result of the predicted increases in population within the region (7). Other reasons for this decline could be attributed to the socio-economic, cultural and natural conditions prevailing in the region.

In addition, policies that govern food production are not being rightly implemented, evaluated and monitored. Among the many possible causes challenging food security is the adoption from many Sahelian countries of external policies and technologies, which have not been suitable to their own situations. The most prominent being the Green Revolution that could not succeed in Africa as it did in South Asia because of the lack of proper institutions and infrastructure. The outcome of its failure was the liberalization of the agricultural sector thereby abolishing the provision of chemical inputs, subsidies and financial assistance to farmers (5). For example, in 1972, the Cameroon government promoted the production of export cash crops such as cocoa, coffee, rubber and cotton. The driving force was the high prices of these commodities on the international market. Similarly, farm inputs were heavily subsidized at the reach of each farmer. This motivated most of them to grow these cash crops as they earn quite huge sums of money from them. However, when the prices of these crops fell drastically in the mid 1980s, coupled with the Structural Adjustment Programme (SAP) of the IMF and WB, the government uplifted subsidies (8). Conversely, today, the European and American agricultural systems remain heavily subsidized because their governments recognise the importance of Agriculture in the economy. The problem of food insecurity in Africa is highly correlated to its economic malaise (1). The fact that a high percentage of the population depend on agriculture for their livelihoods implies that much of their income comes from the sale of agricultural products. Consequently, if production is low, then they will be obliged to consume the food rather than sell to earn income. This limits their purchasing power to a greater extent during periods of crop failure and consequently their food security.

## Role of livestock in West Africa

Livestock rearing plays a key role in the economies of West African countries providing, at times, 44% of agricultural GDP. With 60 million heads of cattle and 160 million heads of small ruminants, 400 million poultry, the Sahel and West Africa is an exceptional region for livestock rearing. In numbers, and in comparison with the entire sub-Saharan Africa region, the Sahel and West Africa contain 25% of the cattle, 33% of the sheep, and 40% of the goats. However, this animal production potential is still rarely optimised and the region continues to import great quantities of animal products to meet the needs of the population. As for dairy products, imports have doubled within 20 years, increasing from 223.7 million USD in 1984 to 529.4 million USD in 2004.

Besides a loss of State revenue, these imports of animal products have been detrimental to the development of local production chains, notably in the dairy and poultry sectors. Growing annually by 4%, the demand for animal products in the Sahel and West Africa should increase more than 250% by 2025. For now, the animal product supply growth rate is at 2%. This increase, although significant, does not satisfy demand.

Statistics indicate that this imbalance between supply and demand will continue and worsen in the 2020s. Besides improving productivity, livestock rearing in West Africa shall increasingly face policy and technical challenges. It is essential to support national and regional trade and agricultural policies that encourage the promotion of domestic animal product production.

This situation raises several worrying questions for partners and actors in development of the livestock sector in the Sahel and West Africa region, especially the following: how can the livestock sector become a driving force in strengthening the regional animal products market? How can the regional supply of meat, dairy and other products be increased, and how can the regional trade in these products be boosted in response to the growing demand of towns? And what could the contribution of livestock rearing be to food security and poverty reduction? The

failure to capitalise sufficiently on this potential because of inadequate policies has resulted in imbalances at several levels. First, at the regional level, animal production in the SWA countries is far from meeting a demand that is now growing at an estimated 4% a year. The second imbalance concerns the low level of trade in animal products among the various zones of the region, which could instead capitalise on their complementary assets in terms of geographical position or agro-ecological potential. The third imbalance concerns disparities between urban and rural areas. For the 11 SWA countries with comparable data, rural poverty (the percentage of inhabitants living on less than two dollars a day) averages out at 58% as against 35% in urban areas. Differences in income between town and country are also reflected in the consumption level of animal products. Styles of urban consumption are changing, with greater attention being paid to the health quality of food and a preference for “high-end” and standardised products. In the short term, strategic orientations must be based on the two main strategic animal products – meat and dairy products – in order to meet a demand of 3.5 million t for meat products (from cattle, small ruminants, poultry and pigs) and 4.5 million t for dairy products by 2015. A second short-term orientation will have to be the boosting of the contribution of the livestock sector to reducing poverty and food insecurity in the various countries. In the long term, the SWA countries must equip themselves with the necessary means of entering the world market in animal products by working towards compliance with health and phytosanitary standards for these products, thus establishing the conditions for fair competition among producers while protecting consumers from improper and dangerous practices. In conclusion, the animal production potential plays a direct role in the process of socio-economic transformation and contributes to people’s nutritional and food security in a number of ways. Livestock rearing as a productive activity is in line with that same dynamic of bringing men and women out of the vicious cycle of poverty that affects rural people in particular but increasingly also those in urban areas – or preventing them from falling back into it. Livestock production not only improves people’s nutritional status, but above all it provides income to various groups on the fringe of African society through trade.

## **Animal production and health in Nigeria**

Although the livestock sector receives little support in the form of public investment in processing and packaging infrastructure and lacks policies to stimulate regional trade in animal products, there are some comparative natural – and exploitable – advantages among the countries of the SWA region. In fact, the coastal countries are better endowed than those of the Sahel in terms of modern short-cycle livestock (poultry and pigs), especially in urban and peri-urban zones. In this regard, Nigeria’s importance must be noted, in as much as it constitutes a market accounting for nearly 55% of the international meat trade in the region (9) and therefore has a determining influence on the livestock sector and the regional trade in animal products (Table 1). As in many other countries of sub-Saharan Africa, livestock account for as much as one third of Nigeria’s agricultural Gross Domestic Product (GDP), providing income, employment, food, farm energy and manure, fuel and transport. Nevertheless, livestock production is faced with a number of constraints, which on the long run results in low productivity and reduced profitability. Some of the major obstacles to productivity in the livestock sector are identified in trypanosomiasis, skin diseases, worm infestations, foot rot and fly (tse-tse) problems (10). The resultant effects of these diseases are poor growth, emaciation, rough hair coat, anaemia, general ill health and death when the condition is severe.

**Table 1. Nigerian livestock population estimates from a 1992 survey**

<b>Species</b>	<b>Number</b>
Chickens	82,400,000
Goats	34,500,000
Sheep	22,100,000
Cattle	13,900,000
Donkeys	900,000
Horses	200,000
Camels	90,000
Other poultry*	31,900,000
Pigs	3,500,000
Dogs	4,500,000
Cats	3,300,000
Rabbits	1,700,000
Guinea pigs	500,000
Giant rats	60,000

\* Includes pigeons, ducks, guinea fowl and turkeys

The majority of the cattle owners usually treat their cattle against these unhealthy conditions but complain that the treatment charges are expensive. Although farmers generally unanimously agree that treatment of animals against these diseases has a lot of benefits (prominent among which is the increase productivity and market value) yet a lot of problems are being faced by cattle owners. Apart from the high cost of drugs and treatment charges, government owned veterinarians and veterinary clinics are insufficient, leading to the existence of quackery in the area. A study carried out in 2000 on cattle production and marketing in Nigeria revealed that, despite the challenges and difficulties, farmers would be nevertheless prepared to make commitment to livestock development programmes. Some of the interviewed people offered different suggestions to the government towards livestock development. Some of the suggestions were concerned with request for incentives like subsidy on veterinary drugs, establishment of veterinary clinics and training of more veterinary personnel including veterinary extension agents among others.

The estimates illustrated in Table 1, based on standardized and systematic methods of sampling, are the most reliable population figures currently available, with standard error margins of less than 5% for major livestock species. In monetary terms, the value of Nigerian livestock resources, based on prevailing market prices in mid-1991, was conservatively estimated to be in the order of US\$ 6000 million.

Poultry outnumbers all other forms of livestock in Nigeria, and, not surprisingly, is found throughout the country, wherever there is human settlement. Although pigeons, ducks, guinea fowl and some turkeys are also widely kept, chickens are by far the most common. Typically they are maintained under traditional, low-input, free-range systems of management, but substantial numbers are also reared intensively on a commercial basis, particularly in the southern states. Commercial holdings account for some 10 million chickens, or 11% of the total estimated population of 82.4 million. A particular mention must be given to the relatively recent bird flu epidemic which hit Nigeria with the H5N1 highly virulent strain. The dreaded bird flu was first confirmed to be in Nigeria in 2006. The last outbreak of the disease was recorded in 2008 in Kano and Katsina. They were quickly contained. Nigeria has enjoyed since then without an outbreak of the virus and remains the only country with a success story although thousands of birds had to be culled.

Small ruminants are almost as ubiquitous as poultry, though not so numerous. There is estimated to be a total of 56.6 million head throughout the country, with goats outnumbering

sheep by three to two. Although some seasonal movement of pastoral sheep does take place, the great majority of small ruminants are sedentary village livestock and their patterns of distribution mirror those of human settlement. With regard to goats, there are three main varieties in Nigeria: the West African Dwarf, the Sokoto Red and the Sahel. Goats are renowned for their hardiness and can survive in most environments: West African Dwarf goats are kept in the forest zones and in the Middle Belt; Sokoto Reds are kept throughout the north; and Sahel goats are restricted to a strip along the frontier with the Niger. Although pastoral Sahel goats are found in the northern semi-arid zone, most goats are kept in villages. The most common production system is that of seasonal confinement. Northern goats were found to be markedly more productive than West African Dwarf goats, with lower ages at first kidding and shorter kidding intervals, although they produced fewer kids per kidding.

There are four main types of sheep native to Nigeria: the Balami, Uda, Yankasa and West African Dwarf. Balami and Uda are kept in the semi-arid regions, West African Dwarf sheep in the south and Yankasa throughout the country. Sheep are the second most numerous pastoral species, and small flocks accompany many cattle herds in the north and in the Middle Belt. A comparison of pastoral and village stock shows that pastoral animals are generally more productive. The productivity of West African Dwarf sheep is substantially lower than that of other breeds. All Nigerian sheep are used for wool, but they are rarely milked. In the north, they are eaten regularly and form part of the daily protein supply, but there is also a marked variation in demand coinciding with religious festivals. As a result, there are dramatic seasonal price fluctuations, and in some areas the household fattening of sheep for sale is a major economic activity.

Cattle are found throughout Nigeria, but they are most common in the northern two-thirds of the country. Seasonal transhumance does take place, but generally to a limited extent. Almost half the total cattle population is permanently resident within the sub-humid zone. Humped zebu cattle are by far the most common, but limited numbers of Keteku, Muturu and Kuri cattle occur in the southwestern, southern and northeastern parts of the country, respectively.

With regard to pig farming, the traditional Nigerian black hairy pig is gradually being replaced by various exotic breeds, including the Large White, Landrace, Hampshire and Duroc. Pigs are generally kept under systems of seasonal confinement in the north and Middle Belt, but they are usually confined all year-round in the south, except in the Niger Delta region. Pigs must be given supplementary feeds, and in village systems the lees of beer are often combined with household scraps for food. The production of pigs is obviously profitable and continues to spread in many parts of non-Muslim Nigeria. In addition, intensive pig rearing is economically viable on the periphery of large cities because of the availability of industrial by-products, particularly brewers' grain. Units of between 50 and 200 pigs kept in concrete pens are common, especially in the densely populated regions of the south. Commercially managed piggeries, with more than five breeding sows, account for about 3% of the total estimated pig population of 3.5 millions. Gradually, through natural selection and co-adaptation, this has led to the evolution of milder forms of the disease and the development of some trypanosomiasis-tolerant zebu cattle populations.

In addition to the more overt, physical aspects of agricultural expansion and environmental change, there is a confirmation of a variety of other more subtle, qualitative changes currently taking place within local systems of agriculture. These include a marked reduction in pastoral nomadism; the increasing sedentariness of pastoralists and their adoption of crop cultivation in addition to keeping livestock (11); the taking up of animal husbandry and livestock fattening by arable farmers, the utilization of crop residues by livestock in exchange for dairy products and/or manure, and the spread of animal traction for ploughing and carting.



Infectious diseases in animals in general and in cattle in particular, are the most common health hazard. Tsetse (*Glossina* spp.) and trypanosomiasis have for many years been regarded as the most important constraints on cattle production within the Nigerian Middle Belt. Today, with almost half the national cattle herd resident in that region of the country throughout the year, this obviously can no longer be the case. Deforestation and the removal of wildlife have greatly reduced the natural habitats and wildlife hosts of the tsetse fly over much of the country (10). With regard to the incidence of single infectious agents, the following in cattle are considered to be the most common in Nigeria accounting for loss of heads and general productivity, with the exception of rinderpest: in fact, after fighting against rinderpest for more than 30 years, a situation that had depleted the country's livestock reserves, the World Organization for Animal Health has certified Nigeria rinderpest-free in the year 2010. Other infectious diseases still affecting cattle population include contagious bovine pleuropneumonia, foot-and-mouth disease, dermatophilosis and Lumpy Skin Disease. Reproductive disorders in general and brucellosis in particular are the most prevalent causes of reproductive and productive loss. In 2009, the Government of Nigeria has placed an indefinite ban on the importation of pigs as part of measures to prevent the spread of the deadly swine fever into the country. In addition, in order to efficiently protect the country livestock reserve and in general to detect infectious diseases and guard against its spread, more animal quarantine stations are being constructed at international airports in Nigeria.

## **Fisheries in Nigeria**

Nigeria's artisanal sector is the largest in the region, with thousands of vessels along the coast, in estuarine areas, and inland that use nets, hooks, traps, and seines. Several hundred small- to medium- sized trawlers, operated principally by smaller firms, fish in coastal waters, mainly in the east. The shallow continental shelf and lack of upwellings reduce the productivity of fishing. In general, the Nigerian fishery is overcapitalized (200 to 300 additional vessels are licensed annually), and existing vessels are slow to adapt to new fishing practices and gear innovations, thereby reducing fleet efficiency. Most fish catch is frozen for distribution to urban centers throughout the country. Some fish (mainly artisanal pelagics) is smoked for distribution to villages with limited cold-storage infrastructure. Smoking occurs in small and home-based enterprises along the coast and around Lake Chad, and is done principally by women. Nigeria has a high rate of domestic seafood consumption – almost all fish production is consumed in country. Shrimp is the only large export; about half of total production is exported. Most efforts to increase production are focused on meeting domestic demand. There is currently little use of processing by-products, such as fish meals and oils, which are generally discarded. Despite the existence of substantial tuna stocks, Nigeria has not participated much in the tuna fishery. Only in recent years has Nigeria landed small amounts of tuna for domestic consumption. There is potential for growth in the aquaculture industry, which the government has supported since the 1960s. Currently, most operations are small and private, but some larger companies are attempting to develop economies of scale.

## **Animal production and health in Cameroon**

The United Republic of Cameroon lies on the west coast of Africa, with Nigeria to the west, Chad and Central African Republic to the east and Congo, Gabon and Equatorial Guinea to the south. The livestock sector in Cameroon accounts for 16% of agricultural production and is an

important means of income for 30% of the rural population. The 3 northern regions of Cameroon account for 75% of the national herd. The most consumed meats are cattle, poultry, pigs, sheep, goat, bush meat and their derivatives products. Local production does not satisfy the demand, reason why a great quantity remains imported. Because of the poor safety measures many of these animals are malnourished and suffer from a number of diseases. Improvement of the quantity and quality can be done at various stages of the farming chain.

Animal products, mainly destined for the domestic market, consist of cattle, goats and sheep, along with chickens, milk and eggs. According to 2005 estimates, the Cameroonian livestock herd consisted of 6 million cattle, nearly 8.2 million small ruminants, 1.7 million pigs and 33.6 million chickens (of which 21 million are in the traditional sector). According to a 2004 evaluation, 62,481 households are engaged in cattle rearing; 176,850 in sheep and/or goat rearing; 51,130 in pig breeding and 198,614 in chicken breeding. Furthermore, according to local authorities, three methods of livestock breeding are used in the case of cattle. The most widespread is traditional free-range breeding, characterized by low yields and involving transhumance. The other methods are ranching – practised by the Animal Production Development Company or else Société de Développement et d'Exploitation des Productions Animales (SODEPA) and a number of other livestock breeders –, and intensive livestock breeding (practised mainly by research centres). Sheep/goat breeding, mainly done in the north of the country, is essentially based on free grazing and achieves relatively high productivity. Pig breeding is developing little by little following the launch of the Pig Sector Development Project, but the market is not well organized. Outside the Kounden plant run by the Ministry of Livestock, Fisheries and Animal Industries (MINEPIA), the local market is mainly supplied by small family farms. Poultry production, in contrast, is organized and, apart from private farms, it includes large-scale operations to supply day-old chicks and fertilized eggs to producer farms. Factory units have also been set up to produce feed for poultry and pigs. According to the authorities, the main problem for poultry production is the high price of inputs, which is passed on to the price of chicken. With regard to cattle, around 75% of the national herd is found in North Province. Another 16.6% is found in West and Northwest Provinces, which include high-altitude pasture lands extending to the Adamaoua Plateau. The cattle in these provinces, which together constitute 92% of the national herd, are generally Fulani or Mbororo Zebu kept in the areas which are free of tsetse or only lightly infested. In the highland areas, such as the Manengouba Mountains near Nkongsambia, settled Zebu herds can be found as far south as the fifth parallel.

Dry-season transhumance is practised in Centre South and East Provinces, which account for 8% of the national herd. There are also a few cattle in relatively settled herds just south of the Adamawa Plateau, near Yoko in Centre South Province and near Garoua-Boulai in East Province. These are also Zebu cattle, often of the Mbororo breed. The distribution of cattle in Cameroon thus appears paradoxical: although more than 80% of the country seems to be infested with tsetse, more than 99% of the national herd is made up of non-trypanotolerant Zebu cattle. There are very few trypanotolerant cattle in Cameroon and very little information on their numbers or characters. Five groups can be identified: there are Kapsiki, or Kirdi, cattle in very localized herds in North Province around Mokolo, and there are also very localized herds of Doayo, or Namshi, cattle in North Province towards Poli. In Southwest Province there are localized herds of Bakosi cattle around Bangem and 'Muturu' cattle towards Buea and Victoria. Finally, small numbers of N'Dama have been introduced in Cameroon and are widely scattered in several provinces. A number of factors at least partly explain the presence of Zebu cattle in the tsetse-infested areas. For one thing, in some areas the tsetse challenge is slight and only seasonal. Cameroon has a high-altitude region, called the Cameroon Dorsal, which starts with Mount Cameroon in the southwest and extends to the Adamawa Plateau. These highland areas

have a very light tsetse infestation or none at all, and they serve as a seasonal retreat for transhumant Zebu herds, allowing them to take advantage of pastures at other times which are only seasonally infested. In addition, Zebu cattle are given chemo-prophylactic treatment for trypanosomiasis on a large scale in Cameroon, which allows them to survive in lightly infested areas. Finally, the government has carried out intensive tsetse eradication programmes around the country. More than 90% of calvings are during the rainy season (12). Milk off takes starts from 1 to 3 months post-calving. Calves are usually weaned at 10.5 months. Some lactating animals are kept at the camping area while the rest of the herd is taken for grazing. Milking is by hand and any milk not required immediately is either boiled and sold as liquid milk or allowed to sour to provide a base for a sorghum or maize porridge (13). Milk is also bartered for grain. When herds are near urban centres they are the major, perhaps only, source of fresh milk for urban dwellers. In remote areas only a very limited amount of milk might occasionally be sold because of the distance from markets. A major constraint to supplying milk to urban populations is the effective marketing of the milk potentially available from pastoral herds. Demand for milk in urban centres is greater in the dry season than in the wet but, in the dry season with cows on transhumance, pastoralists cannot take advantage of this increased demand. In the wet season, when cattle herds may be adjacent to urban centres, demand for milk is low and prices are depressed. The opportunity to capitalize on the demand for milk, coupled to the need to promote more productive dairy systems, has led to the importation of European type dairy cattle. With regard to small ruminants, it seems that more than 50% of the sheep and goats in Cameroon are found in North Province and another 26% in West and Northwest Provinces. Southwest, Littoral, Centre South and East Provinces, all of which are infested with tsetse, account for 853,400 sheep and goats, or 23.2% of the national flock, with 500 000 of these in Centre South Province. Vallerand and Branckaert (14) suggest there are three goats for every two sheep in Cameroon. The sheep and goats of southern Cameroon seem to be of the typical Djallonké or West African Dwarf type. The sheep on the Adamawa Plateau are of this type, but tend to be larger, while in the extreme north the sheep are intermediate between the Djallonké and the Sahelian types. Sheep and goats are found throughout the country, particularly in the villages of the humid forest areas in the south. They seem to be very well adapted to diverse ecological conditions, from the humid forests to the high-altitude zones. Statistics show that the poultry sector succumbed to the numerous crises of the recent years and weekly production slumped from 600,000 chicks to barely 60,000 in 2009. A concerted action jointly carried out by MINEPIA and that of the Economy, Planning and Regional Development (MINEPAT) in 2009 conclude that “With the growth in population, it is necessary to organise the poultry sector so that we know exactly how many kilograms of chicken we need to produce to be eaten in a specific period”. Imports consist mainly of poultry and milk, in addition to cattle on the hoof (often on an informal basis) from the Central African Republic and Chad. Poultry imports have grown substantially since 2000, and mainly consist of frozen chicken sold at a quarter of the price of live poultry on local markets. In 2006, the Citizens’ Association for the Defence of Collective Interests conducted a campaign to restrict imports of frozen chickens from Europe and Latin America and to promote the local poultry sector.

There is very little precise information about diseases among humpless cattle in Cameroon because the efforts of the Veterinary Services are aimed exclusively at the Zebu herds, which are more numerous and which require a variety of veterinary treatments. The humpless cattle seem to be well adapted to their environment and resistant to most diseases. The only treatment they seem to have received is vaccinations over the past few years. In the Doayo area, there are traditional accounts of periodic epidemics, probably of rinderpest or Contagious Bovine Pleuropneumonia (CBPP), and most animals now seem to be vaccinated against these diseases. Trypanosomiasis does not seem to be a serious problem.

## Fisheries in Cameroon

Cameroonian fisheries have undergone considerable development during the two decades 1960-80. The industrial sector has undergone relatively more development than the artisanal sector which is still operating at a low commercial level. It has already been demonstrated in Cameroon that haphazard changes in fishing strategy could result in a decline in catches and catch rates with serious socio-economic consequences. In light of this, the Government has, in the Fifth Development Plans (Ministry of Economic Affairs and Planning, 1981) outlined objectives for the fishery sector: i) reorganization and renewal of the industrial fleet through establishment of a National Fishing Corporation; ii) feasibility studies on developing deep-sea fishing; iii) establishing fishing agreement with neighbouring countries exploiting the same resources; iiiii) enforcing fishing zone regulation (2-mile limit) and checking fishing gear restrictions; v) research studies to ascertain need for establishing fishing season limits; vi) establishing an effective fishery statistics system; vii) patrolling waters and controlling any infringements; viiii) modernization of artisanal fishing craft; viiiii) development of artisanal fishing techniques; x) creation of a development authority for small craft sea fishing (MIDEPECAM). Cameroon's industrial marine fleet consisted of 40 vessels in 2002, and ship capacity is on the rise. The artisanal fleet is 30% motorized and uses a variety of lines, seines, and nets to capture mainly bonga, sardines, and shrimp. Inland fisheries stretch across Cameroon's numerous inland waterways to Lake Chad, and aquaculture has been the subject of interest for the government, sharing its intentions to privatize the industry. Good condition of cold-storage infrastructure along the coast allows most of the industrial fish catch to be marketed in either frozen or fresh form, whereas most shrimp are frozen and exported whole. The artisanal fish harvest is generally smoked or dried before being distributed for sale. Catch-limit violations, illegal fishing, and trans-shipment are significant problems in Cameroon, and the introduction of new economic actors and a restructuring of the existing fleet would lead to greater economic gains in the fishing sector. Improving fishing gear technology would also increase efficiency. A project is currently underway to reduce post-capture waste. Cameroon has limited marine resources because its Exclusive Economic Zone (EEZ) is interrupted by the Equatorial Guinean Island, Bioko, resulting fewer strong ocean currents. Finally, inland fisheries have recently experienced diminished productivity after years of exploitation.

## Conclusion

Food security and food sustainability has to go through a number of interlinked processes, both at the level of government decision-making and implementation, as well as within the various technical steps to be taken at the regional and local level. We have seen how both Nigeria and Cameroon have great potentiality in terms of agricultural land availability and livestock reserves. Human growth and food demand though, are rising faster than what agriculture and livestock rearing can offer, and therefore immediate and efficient measures have to be taken. Some of such measures can be summarized into the following: i) capitalize into the best available internal resource; ii) stimulate and spread the livestock and animal product trade nationwide and among neighbouring countries; iii) optimize the livestock productivity through diffusion of newly developed reproductive and production technologies whenever and wherever feasible; iiiii) provide state-of-the-art training to veterinarians and extensionists for better monitoring of infectious diseases and animal production parameters, and v) sustain an agricultural policy addressing nutritional and safety qualities to prevent zoonosis and protect public health.

Finally, improvement of science and technology research will help enhance animal food production, fish, poultry, small ruminants and pigs; ameliorate the animal health and boost incomes generated by this sector. As a result we may witness an increase in the availability of animal protein sources, be more efficient in combatting child and pregnant women malnutrition. More animal produce and of better quality will increase the competitiveness of local products on the job market and encourage economic growth, contribute to the national poverty reduction strategy and help meet the Millennium Development Goals challenges.

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## **RISKS TO BENEFITS OF LOCAL FOODS: THE CASE OF RED PALM OIL IN CAMEROON**

Wilfred A. Abia

*Integrated Health for All Foundation (IHAF), NGO, Cameroon*

### **Introduction**

Generally, in many developing countries like Cameroon, people pay little attention to the kind of food they eat; whether it is balanced or not or whether it will be beneficial or stand as a risk to their health. Local food is food that is grown within a reasonable distance from where it is eaten. Exactly how local food is defined is as varied as the consumers that buy it. What is common amongst local food consumers is a commitment to purchase food that ensures social, economic, and environmental sustainability. Buying local food reduces the number of “food miles” between farm and plate, and helps to keep agricultural profits in the local economy. Practically speaking, local food production can be thought of in concentric circles that start with growing food at home. The next ring out might be food grown in our immediate community - then division, region, and country. For some parts of the year or for some products that thrive in the local climate, it may be possible to buy closer to home. At other times, or for less common products, an expanded reach may be required.

People who value local as their primary food criterion are sometimes referred to as “locavores”. The term “locavore” was coined by Jessica Prentice from the San Francisco Bay Area for World Environment Day 2005 to describe and promote the practice of eating a diet consisting of food harvested from within an area most commonly bound by a 100 mile radius. It is also considered as a collaborative effort to build more locally based, self-reliant food economies- one in which sustainable food production, processing, distribution and consumption is integrated to enhance the economic, environmental and social health of a particular place and is considered to be a part of the broader sustainability movement.

Local foods are mostly organic that is, very little or no fertilizers are used in their production, and they are produced in local farms and nearby gardens, making them very natural and fresh (for example, plantain, cassava, vegetables, cocoyam, yams and sweet potatoes from Cameroon). Unlike the western or developed worlds (Americas and Europe) where mostly processed and fast (or canned) foods are being consumed by the people, local foods are produced, distributed and consumed in many African countries, especially in Cameroon, often times referred to as the “food basket of Africa”. In all local communities of Cameroon, indigenous people practice and depend sorely on subsistence agriculture (farming).

Notwithstanding, whether local or conventional, food is an essential prerequisite for life. As a result, the primary goal of eating and drinking is to enable the body to function normally. Therefore, a certain recommended amount of food with variety of nutrients in recommended levels (balance diet) for different consumer categories is necessary to keep the body in good condition (proper physiologically active). Meanwhile good quality food makes health (benefit), bad quality ones give rise to several diseases (risk).

Food plays very vital role in maintaining proper health and also helps in the prevention and cure of diseases. The purposes of food intake are to promote growth, to supply force and heat, and to furnish materials for the repair of waste that is constantly taking place in the body. The various elements found in food are carbohydrates (starch/sugar), lipids (fats/oils), protein

(nitrogenous), and mineral elements (inorganic). When used alone; none of the food elements are capable of supporting life. True food substance contains some of all the food elements, the amount of each varying in different foods.

Meanwhile good quality food intake makes health (benefit), bad quality food intake is a source or route of health disorders (risk). Food is beneficial to health due to its nutritive components, and the quantity available. Carbonaceous food, which comprises the bulk of most food furnish the body with materials for the heat production; serve as source of force when taken in connection with other food elements; and in addition, replenish the fatty tissues of the body. Similarly, the nitrogenous food elements especially nourish the brain, nerves, muscles, and all the more highly vitalised and active tissues of the body and serve as a stimulus to tissue change. On the other hand, the inorganic elements, especially phosphates, aid in furnishing the building material for bones and nerves.

Food is one of the most important cultural markers of identity in contemporary societies, and it has provided a medium for the understanding of social relations, family and kinship, class and consumption, gender ideology, and cultural symbolism. Much scholarly attention has been on the social and cultural construction of foodways; however, a truly comprehensive view of food cannot neglect the politics of food production, in particular, how, when, from where and even why different kinds of food are produced, prepared and supplied. Indeed, food also gives a people a sense of belonging. Local foods have the following advantages due to their natural or organic state:

- *Better health.* Since organic food is not prepared using chemical fertilizers and pesticides, it does not contain any trace of the strong chemicals and might not affect the human body. The freshness of ingredients makes food unrefined and natural, such as portage plantains (also called born-house plantain), roasted yams and red palm oil, Eru, Koki, just to name a few.
- *Better taste.* People strongly believe that organic food tastes better than inorganic food. The prominent reason for this belief is that it is produced using organic methods. Furthermore, organic foods are often sold locally resulting in availability of fresh produce in local market.
- *Environment safety.* As harmful chemicals are not used in organic farming, there is minimal soil, air and water pollution; thus ensuring a safe world for future generations to live in.
- *Ease digestion.* Local foods are rich in fibre contents; a good example is *Gnetum africanum* Welw (eru), thus easing digestion process. This factor makes local foods very good for the bowels.

Local foods as Leafy-Vegetables (LVs) are also in their natural state. They are extremely beneficial to health such as the huckleberry (“njama-njama”), bitter leaf, leaves of *Manihot esculenta* Crants locally called cassava (“nkwem”), cabbage, cocoyam leaf (“etawh”) and bush okra (“contry-mango or button”). Almost all these LVs, especially Dark-Green-Leafy-Vegetables, are good sources of micronutrients such as iron, selenium and zinc, as well as vitamins A, B complex, C and E. A notable example is amaranth (“green”), which has more iron, calcium, and vitamin A than non-indigenous species like lettuce, spinach or green cabbage. Similarly, *Gnetum africanum* Welw (“eru”) and leaves of *Manihot esculenta* Crantz (cassava) which are rich in proteins and almost comparable to protein level in soy. *Gnetum africanum* Welw (eru) from Cameroon is very rich in iron and zinc contents as reported by Abia *et al* (1). Eating healthy foods is one of the greatest ways you can live healthy and combat developing a

disease. Some diseases are genetic and there's not much you can do about that. But others like diabetes 2, lung cancer and heart diseases might be prevented via diet appropriation (2).

### **Some potential risks in case of an overdose of nutrient(s)**

Meanwhile it is important that our food contains some of all the various food elements, experiment on both animals and human beings have revealed that some elements especially carbonaceous and nitrogenous elements be used in certain definite proportions, as the system is only able to appropriate a certain amount of each; and all excess, especially nitrogenous elements, is not only useless, but even injurious to the body (3).

We eat to live and not live to eat, as such eating should be done with moderation since it can be detrimental to one's health. For example, an excess consumption of fatty elements can lead to a massive or an exaggerated accumulation of adipose tissues, consequently causing obesity, later diabetes, hypertension and or any other heart related disease. Similarly, excess protein intake leads to gauds; malnutrition leads to kwashiorkor, etc.

## **Oil palm farming and red palm oil processing**

Red Palm Oil (RPO), otherwise known as palm oil, is derived from the fruits (locally called "mbanga" in Cameroon) of the palm tree (*Elaeis guineensis*) that originated in Tropical Africa. Specifically, RPO is extracted from the pulp of its fruit. Now it is grown in other parts of the world. It is called RPO because of its natural reddish hue, due to the high amount of carotenes it possesses. Do not confuse palm oil with the oil that comes from the kernel, or seed called Palm Kernel Oil locally referred to in Cameroon as "miyanga". The palm fruit develops in dense bunches weighing 10 kilograms or more and containing more than a thousand individual fruits similar in size to a small plum. Palm oil is abundant in both saturated and unsaturated fats.

### **Oil palm farming in Cameroon**

In the 1990s agriculture was the principal occupation of over 62% of the economically active population in Cameroon, although only 15% of the land was arable. One of the major cash crop is oil palm (*Elaeis guineensis*) which is a very high potential perennial oil crop. According to Bakoume and Mahbob (4), only about 100,000 ha of the over 25 million ha of the oil palm distribution areas are currently being planted. The hope to plant more and increase the palm oil production rest with smallholders who are highly motivated and are found all over the national oil palm distribution area. The availability of land, the diversity of climates and keen interest of locals to increase national palm oil production are the determining factors for the future good performance of the palm oil sector (2). This is not without good-quality planting materials, and availability of technical assistance to smallholders for good crop management aimed at increasing yields, improving quality and maintaining low production costs.

According to Ngoko *et al.* (5), smallholders oil palm production in western highlands of Cameroon lost about US \$ 200.00 per hectare due to use of poor quality planting materials and inadequate cultural practices. In addition, low yield and bunch failure observed were due to the quality of planting material, which was essentially made of seedlings picked under natural palms or improved tenera and constituted of tenera (52%), psifera (22%) and dura (26%). Vascular wilt caused by *Fusarium oxysporum* f.s. elaeidis was the most significant fungal disease observed in most of the fields with an average incidence of about 30%. It has also been



responsible for bunch failure in dura and tenera palms whereas bunch abortion in psifera palms is a natural phenomenon. The use of appropriate cultural practices and Fusarium tolerant improved tenera may increase both the productivity of the oil palm farms and house hold revenue.

### **Socio-economic importance of oil palm**

Oil palm is economically important as a high yielding source of edible and technical oils. An oil palm fruit contains about 56% of oils (25% on a fresh fruit bunch basis) which is edible with no toxins. It is thus suitable for small-scale processing. An estimated RPO production in 1999 stood at 160,000 tons. It is a major source of income to several local populations that exploits the natural groves to process red palm oil traditionally. Although the traditional (local) process is simple, it is very tedious and inefficient and cost ineffective. An epitome of such communities is Menka community in the North West region of Cameroon. There are lots of palm plantations, especially in the south west region of Cameroon. Two of such popularly known plantations are the PAMOL, and the Cameroon Development Corporation (CDC).

The RPO is very nutritious oil, rich in Pro-vitamin A and vitamin E. It is a major source of edible and many industrial products. A majority of African dishes, especially in Cameroon are prepared with palm oil. It is the widest and most popular cooking medium in Cameroon. RPO is 15 times richer in beta-carotene (a form of vitamin A that protects our body from many diseases) than carrots. Also, cooking palm fruit oil remains the largest source of tocotrienols (a form of vitamin E) known to man. The freshness of its ingredients makes the food unrefined and natural for example portage plantains (also called “born-house plantain” which is crushed roasted plantain mixed with RPO), similarly, roasted yams and RPO, “eru soup”, “koki”, “mbanga soup” just to mention a few.

RPO has been in use for over 5000 years, both for nutritional as well as medicinal purposes. In Cameroon, apart from cooking and export, RPO is used as an anti-poison substance. Though it has been in use for so many years, it is only now that scientists have begun researching about its benefits on our health and well being. RPO is rich in vitamins, antioxidants and phytonutrients, which are essential for good health. It is dark red in colour, due to the presence of a compound called carotenes, which also give carrots and tomatoes their colour. The red colour appears because of the combination of the alpha-carotenes, beta-carotenes, and lycopene. Other nutrients that red palm oil contains include: vitamin K, CoQ10, squalene, phytosterols, flavonoids, glycolipids, and phenolic acids. Unlike other cooking oils such as olive oil, that lose their nutrients upon heating, RPO retains all of its nutrients and is therefore popular as cooking oil.

### **Red palm oil processing**

#### **Modern (standard) processing method**

Until the early years of the twentieth century, palm oil was processed only by traditional village methods, by which loose fruits were collected from the ground or a few bunches were cut from the tree. Beginning in the 1920s, however, the United Africa Company and British colonial officials in Nigeria started experimenting with steam cookers and hand presses designed to make production at the village level more efficient in terms of labour use and oil yield. Yet a lack of cash prevented most farmers from trying the new machinery, with the exception of a few lucky recipients of free samples or government subsidies in the 1940s (6).

A separate process of trial and error led to the development of the sophisticated factories required to deal with the volume of fruit produced on modern plantations and to produce oil of the high and standardized quality that would appeal to Western food processors. Such factories

handle almost all the palm fruit of Southeast Asia, whereas in West Africa and Latin America, processing is carried out by a wide variety of methods, yielding oil for local consumption and for industrial as well as edible uses in the West.

Whatever the scale and sophistication of the process, the following main steps are required:

1. Separation of individual fruits from the bunch.
2. Softening of the fruit flesh.
3. Pressing out of the oily liquid.
4. Purification of the oil.

### **Traditional (local) processing method**

Whole, ripe, fresh fruit bunches (FFB) are cut from the palm. With young trees this can be done from ground level. With older trees in West Africa, harvesting is still often accomplished by a man climbing the tree, secured to it by a loop of rope or other locally available materials, such as rattan and raffia fibre (6). This is similar with the case of Menka-Cameroon where after harvesting, the cones or bunches of oil palm fruits are kept for 2 to 5 days at home to get ease stripping. Thereafter the oil palm fruits are threshed or dislodge with machetes from the cones and allowed for 3 days to completely mature. Later it is hand-picked to empty the bunches. Selected oil palm fruits are then cooked with water in drums at 100 °C overnight and after cooling, pounded on traditional processing platform (“chum”). Under feet is used to smash the cooked oil palm fruits to separate nuts from the pulps or mash which intend is hand pressed to separate the oil from the chaff. The various components are then washed with water while the extracts of RPO floats on the surface of water pool where where it is later collected by hand-gathering alongside traces of water. Finally, the collected RPO is dried by dry cooking for about 1 hour and preserved in plastic or rubber containers (1, 5, 10, 20, 25 litres) ready for sale. Both the recovered nuts and chaff are used as fuel for cooking (2).

However, in plantations such as CDC and PAMOL in Cameroon (which uses non-traditional or standard methods), a curved knife attached to a bamboo is used. After cutting, most of the fruits are still firmly attached to bunches, which are divided into a few sections, heaped together, moistened, and covered with leaves. Natural fermentation during two to three days loosens the fruits so that they can be picked off the bunch sections by hand.

Following this step, two major variants in the process are used to produce two oils with different characteristics – those of soft oil and those of hard oil. The regions producing each type have changed since Julius Lewkowitsch (6) identified Salt pond in present-day Ghana as the cheapest source of hard oil, and drawing on the Ivory Coast as the best place to buy soft oil. But the basic methods have changed little since they were first described by colonial officials in the 1910s and 1920s (6).

For soft oil production, the fruits are separated as soon as they are loose enough and boiled with water for 4 hours to soften the flesh, which is very fibrous. The cooked fruit is emptied into a large container, which may be a pit lined with clay, an iron drum, or a large wooden mortar. It is then reduced to a pulp with pestles or by treading it under foot. The resulting mash may be diluted with water, and the oil is skimmed off or squeezed out of the fibrous mash by hand. In some instances, a sieve made of palm fronds is used to retain the fibbers. At this stage the liquid product, which contains oil, water, and fruit fibbers, is often boiled up with additional water and skimmed again, although this step is omitted in some cases. Finally, the oil is again heated to boil out the residual water.

Lewkowitsch (6) also reported on the preparation of small quantities of oil for kitchen use directly from freshly picked fruit, by boiling the fruit and skimming the oil. Such oil had good keeping properties and often free fatty acid content below 2%.

In the hard-oil process, the fruit is allowed to ferment for 3 or more days longer than in the soft-oil process, until the flesh is soft enough. It is then pulped by treading underfoot in an old canoe or pounding in a mortar. Oil is allowed to drain out for up to 3 days, then water is added, and the mix is trodden again. Further oil rises to the surface and is skimmed. The oil is boiled up with water in another container and finished as described for soft oil.

These two processes differ in some important respects. The prolonged fermentation in the hard-oil process results in a much greater enzymic breakdown of the neutral fat and, therefore, in a much higher free fatty acid content. The yield obtained by this process is also much lower. However, it has a substantial advantage in that the labour and firewood requirements are also much lower.

### **Mechanization of the small-scale process**

With the rapid twentieth-century growth in West African exports became the introduction of simple machines to reduce labour requirements and increase oil yield from a given quantity of fruit. Early machines, before and after the 1914-18 war, as described by Hartley (6), included a cylinder fitted with manually operated beaters, which was fed with softened fruit and hot water. After "beating," an oil-water mixture was run off through a sieve. Another system used a special cooker and a press as adjuncts to the soft-oil process.

The first device to become widely adopted, however, was a modified wine and cider press: the Duchscher press. This consisted of a cylindrical cage of wooden slats, held in place by iron hoops, and a ram on a screw thread. The screw thread was turned manually by means of long bars (in the manner of a ship's capstan), forcing the ram onto the pulped fruit. The exuding liquid was collected in a trough surrounding the cage.

Similar presses, but using a perforated cylindrical metal cage, are still in use today, giving yields of 55 to 65% of the oil present. A recent analysis of the needs for mechanization in the village has concluded that this is still the most practical implement, because it can be made and maintained locally and is inexpensive by comparison with other presses (6). However, farmers in Nigeria (which was once the world's largest exporter of palm oil) have, since the 1950s, been reluctant to invest in this or other improvements because of the low producer prices offered by the state-controlled marketing boards. It is to be hoped that recent reforms of marketing structures in Nigeria and elsewhere in Africa will encourage renewed innovation at the village level (6).

The next development in pressing was the introduction in 1959 of the hand-operated hydraulic press by Stork of Amsterdam. This was capable of processing 600 to 1,000 pounds of fruit per hour and could recover 80% of the oil present. The hydraulic mechanism was later motorized.

A different approach to mechanization brought forth the Colin expeller (first patented in 1904), which in essence is similar to a domestic mincer. It consists of a perforated cylindrical cage, fitted with a spiral screw or "worm," which is turned manually through a gear. Cooked fruit is fed to the worm through a hopper, and the pressure developed as the worm pushes the fruit forward forces oil out through the perforations. Spent fiber and kernels are discharged at the end of the cage. The machine has a capacity of 100 kg cooked fruit per hour, or 250 kg per hour if motorized. The Colin expeller became popular after 1930, mainly in Cameroon. Its limitations were a reduced efficiency with Dura fruit, which forms the bulk of the wild oil palm crop; rapid wear of the screw; and a relatively high cost. The principle of the expeller, however, has been further developed into the screw press found in all modern oil mills (6).

The presses described here provided a relatively efficient process for the step of pressing out the oily liquid during oil production and led researchers to seek improvements in the other steps. Several innovations have resulted from a project begun by the Nigerian Institute for Oil Palm

Research (NIFOR) during the 1950s in cooperation with the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Development Program (UNDP).

The following unit operations and equipment are involved in palm oil production:

- Fruit bunch cookers, which are wood-fired cylindrical tanks. They are loaded with cut-up fresh fruit bunches (FFB).
- A bunch stripper operated by hand, which consists of a cylinder made up of slats and turns on a horizontal axis that tumbles the cooked bunch sections until the individual fruits separate from the bunch and fall between the slats.
- A digester (to break up the softened fruit and release its oil from its cells), consisting of a horizontal cylinder in which beater arms rotate, driven by a small diesel motor.
- A hydraulic press, which was introduced in 1959.
- A clarification unit consisting of two linked tanks, whereby heating with water causes the oil layer in the first tank to overflow at the top into the second tank. There it is dried by the waste heat from the fire under the first tank.

Extraction efficiencies of 87% at a free fatty acid (FFA) level of below 4% are routinely attainable by this process. Between a quarter and a half ton of fresh fruit bunches per hour can be processed, depending on cooker capacity.

A number of variants of this process are in use:

- Bunches are allowed to ferment so that only loose fruit is loaded into the cooker. This variant yields oil of higher FFA.
- The hydraulic presses may be driven by a small diesel engine.
- Clarification can take place in simple tanks with direct heating.
- Cooking of bunches may be by steam, whereby whole bunches are loaded into a tank fitted with a perforated plate about 15 centimetres (cm) from the base. Water is boiled under the plate, and the steam penetrates through the bunches.

In Ghana, an interesting operating procedure has been developed, in which the mill owner provides mill facilities to the farmers, who are then responsible for the bunch stripping and cooking of the fruit. Mill operatives carry out digesting and pressing procedures, after which the farmers take away the oil from their own fruit for clarification (6).

### **Larger-scale processes**

The small-scale processes just described are suitable for the processing of FFB from wild oil palm groves or from smallholdings. The main objective is to produce red palm oil for traditional food use.

The processing of the large quantities of fruit produced by plantations or by large smallholder cooperatives, however, requires a progressively greater degree of mechanization and mechanical handling as the quantity increases. Furthermore, since oil produced on a large scale is usually intended for export or for local refinery processes, the ultimate objective is a neutral oil of bland flavour and nearly white colour. To attain this quality, the processes (including the handling of FFB) are designed to minimize the development of free fatty acids and oil oxidation.

A simple factory process of intermediate scale, in which the material is still handled manually between processing stages, is the Pioneer mill, which was developed by the United Africa Company around 1939. It is designed to process about three-quarters of a ton of fruit per hour, which is the equivalent of about 1 ton of fruit bunches, following the removal of the fruit from the bunch stalks. The process consists of the following steps:

- Autoclaving. 200 kg of fruit is loaded into a vertical batch autoclave mounted on a gantry and cooked under steam pressure of 20 pounds per square inch for 15 minutes.

- After cooking, the fruit is discharged by gravity into a digester provided with a stirrer which breaks it up and releases the oil from the cells.
- The resulting mash is treated in a basket centrifuge, operating at 1,200 revolutions per minute.
- The oil flowing from the centrifuge passes through a screen to remove the fiber, and then to a settling tank.

The settling tank contains a layer of hot water, and the oil is pumped in below water level. The water is boiled for 15 minutes and then allowed to settle. The oil layer is decanted through a hot-water layer in a second settling tank.

The tank is heated to boiling point for 15 minutes and allowed to settle. The clean oil is put into drums.

The sludge from the two settling tanks is further treated by boiling and settling, and the residual oil is recovered.

An oil mill of essentially the same design, with a capacity of 2 to 3 tons of fruit per hour, was featured in the Wembley Exhibition of 1924 by Nigerian Products Ltd., Liverpool, and was apparently demonstrated in operation there (6). In 1950 there were 13 Pioneer mills in operation in Nigeria. The numbers increased to 65 in 1953 and more than 200 in 1962, producing about 25,000 tons. But, subsequently, their use has declined (6).

The Pioneer mill cannot meet the needs of well-established plantations generating large volumes of fruit. To keep costs down and output up, it is vital to have a fully mechanized power-operated mill. The development of such mills began in Cameroon and in the Congo before World War I. Mills using centrifuges for oil extraction were in operation in the Congo in 1916, in Sumatra in 1921, and in Malaysia in 1925 (6). Centrifuges were largely replaced by hydraulic presses in the 1930s, although they were still being operated at Batang Berjuntai, Malaysia, in 1982. Batch-fed hydraulic presses were, in turn, replaced by continuous screw presses, which saved labour and handled much larger volumes of fruit. At this final stage of innovation, the development of agricultural and processing technology went hand in hand. The screw press tended to mangle the fruit of the Dura palm, with its relatively thin layer of oil-bearing mesocarp, but proved ideally suited to the Tenera variety (6).

The principal steps involved in the production of palm oil today are the following: harvest at optimum ripeness; transport FFB to an oil mill with minimum bruising; transfer FFB to sterilizing cages; sterilize FFB by steam under pressure; transfer cooked FFB to a bunch stripper; transfer fruit to a digester; press in single-screw or twin-screw press. The oily discharge from the press, containing water and fruit debris, is passed through screens and settling tanks. The oil phase from the settling tanks is passed to a clarifying centrifuge. The sludge, or heavy phase, from the settling tanks is centrifuged and the recovered oil returned to the settling tanks.

## **Red palm oil benefits**

### **Benefits for health**

The saturated fat in palm oil has been linked to heart disease and other potentially fatal conditions. The "palm oil Action website" suggests that an increase in the consumption of saturated fatty acids is linked to an increase risk of coronary heart disease, stroke, and diabetes. Foods high in saturated fat such as palm oil can raise blood cholesterol. Consequently, it recommends limiting saturated fat intake to less than 7% of total daily calories (American Heart Association).

All of the essential fatty acids that red palm oil contains are essential for the proper growth and development of the human body. The oil also supplies quite the selection of vitamins, antioxidants, and phytonutrients that are also important for good health. To sum it up, here is a list of all the health benefits that red palm oil provides:

1. Both alpha-carotene and beta-carotene are vitamin A precursors, also known as provitamin A; this means that once the body has these carotenes, it is able to make vitamin A. Red palm oil is one of the richest dietary sources of this essential vitamin. In fact, it contains more than carrots and tomatoes combined. Those who are lacking vitamin A or provitamin A in their diet suffer from blindness or other vision problems, weakened bones, weakened immune system, and even affects normal mental functions. Since carotenes require fat to be converted into vitamin A, red palm oil serves as the perfect solution, and helps those who consume this oil by preventing all the above mentioned problems.
2. Red palm oil has plentiful amounts (in fact, the most abundant of any natural dietary source) of vitamin E, which is in the form of tocopherols and tocotrienols.
3. The antioxidants (tocopherols, tocotrienols, and carotenes) that red palm oil contains are very potent and help fight off free radicals that can damage cells in the body. The benefits of antioxidants include providing protection against cancer and heart disease, and slowing the aging process.
4. Some of the other health benefits that have been researched are: improved blood circulation; improved blood sugar control; improved nutrient absorption by the body; stronger bones and teeth (7).
5. When consumed during pregnancy can improve both the mother's and the baby's vitamin A status. Mothers who like wise are breastfeeding may also be able to enrich their milk with vitamin A, which is necessary for the healthy growth and development of children.
6. It is being looked at for the treatment and prevention of malnutrition because it is abundant in many different nutrients. Government programs that want to be undertaken to eliminate nutritional deficiencies, the food should incorporate red palm oil. This will give the sufferers all the nutrients required by their body.
7. Though red palm oil contains a high amount of saturated fat, studies have shown that the consumption of red palm oil in fact prevents heart disease. This is possible as it has the ability to remove the build up of plaque in the arteries, and thus even bring down cholesterol levels. However, it has been advised to consult a doctor before you begin the intake of red palm oil, if you are at the risk of heart disease.
8. Another way in which red palm oil can protect the heart is by stabilizing blood pressure levels. Due to its antioxidants, red palm oil also reduces the possibility of inflammations of the arteries. This helps in keeping the blood pressure levels under control.
9. The regular consumption of palm oil has shown to reduce the risk of developing cancer. This is because of the tocotrienols that contains anti-cancer properties, and help in preventing skin, pancreas, liver, lung, colon, stomach and prostate cancer. However, the best results have been experienced against breast cancer.
10. The antioxidants in red palm oil also help in the protection of neurological degeneration. Thus, the degeneration of the brain, caused due to stress is prevented upon the intake of red palm oil. Thus, brain problems such as Alzheimer's disease, Parkinson's disease and even schizophrenia are kept at bay.

### **Benefits for skin and hair**

Apart from the benefits to our health, the intake and application of red palm oil is perfect for a variety of skin conditions. Red palm oil works as a great solution to heal old scars, including

scars from acne, and even stretch marks. This is because it has a high vitamin A and vitamin E content. Since red palm oil is unrefined, its nutrient value is higher, and thus helps as a solution for skin problems. The application of red palm oil on the face also keeps the signs of aging at bay, leaving your skin looking fresh and young. Before you sleep at night, apply palm oil and leave it overnight. It will repair all the damage that has already afflicted your skin, and will also prevent it from further damage. Red palm oil has moisturizing properties. Those suffering from skin diseases such as psoriasis and eczema will find relief with the application of red palm oil over the affected area. Because this oil is red in colour, it is going to leave your skin looking slightly orange, unless you completely rub it.

Packed with vitamin A and vitamin E, red palm oil is the perfect remedy for those who suffer from hair problems. When used on the hair, red palm oil has a great conditioning effect, and is the perfect remedy for dry hair. Just massage a small amount into your hair, and let it be for about half an hour. Follow your usual shampoo and conditioning routine. You will notice that your hair is left feeling much softer and also has a lustrous sheen. If you use red palm oil for hair regularly, you are bound to have naturally soft and silky hair. Use only a small amount as it is difficult to rinse out larger amounts. Due to its rich amounts of vitamin E, not only does the use of red palm oil help premature hair loss, but several people have experienced that it has helped restore hair among those who had started showing signs of baldness (8).

## Cooking and other uses

Red palm oil has been an international cooking favourite for centuries. In Africa and Southeast Asia, red palm oil is a staple in both the household and in cooking. It is good to use for cooking because it is more heat stable than other cooking oils, meaning it can withstand higher temperatures and still retain its form and nutritious properties; it is useful in both baked goods and cooking. It's very distinctive taste is loved by those who use it.

In addition to getting palm oil in through dietary sources, it has other conventional uses of interest. Because it is packed with certain fatty acids (myristic and lauric), it is useful in the manufacturing of soaps, washing powders, and personal care products. Lauric acid is very important in soap making because it allows for a quick lathering when the product is being used.

It is used for biodiesel fuel purposes. In most communities in the south west region of Cameroon that palm oil is produced, the chaffs are used as fire wood in cooking.

In West Africa, palm oil has a wide range of applications. It is employed in soups and sauces, for frying, and as an ingredient in doughs made from the various customary starch foods, such as cassava, rice, plantains, yams, or beans. It is also a condiment or flavouring for bland dishes such as *fufu* (cassava). A basic dish, "palm soup," employs the whole fruit.

In the case of palm soup, first wash and boil palm fruits. Next, pound the fruit and mix with water to a paste. Add meat or fish, vegetables, onions, spices, and salt. Boil for 25 minutes and cook for a further 15 minutes. Serve the soup with cooked "kwacoco" (grated cocoyam tied in plantain leaves), rice, yam, plantain.

Oils and fats generally are susceptible to attack by atmospheric oxygen, resulting in rancidity. Virgin Palm Oil contains tocopherols (Vitamin E) which are powerful natural antioxidants. Therefore, it has exceptional resistance to rancidity. Virgin Palm Oil is known for its excellent stability at high temperatures.

## Super anti-oxidants and carotenes Nature's Abundant Source

Vitamin E is one of the most important phytonutrients in edible oils. It consists of eight naturally occurring isomers, a family of four tocopherols (alpha, beta, gamma and delta) and four tocotrienols (alpha, beta, gamma and delta) homologues. While most Vitamin E supplements on the market today are composed of the more common tocopherols, tocotrienols are believed to be a much more potent antioxidant than tocopherols. Tocotrienols are naturally present in most plants, however they are found most abundantly in palm oil extracted from palm fruits. Other sources are rice, wheat germ, oat and barley. It has been shown by published research that alpha-tocotrienol is more potent than alpha-tocopherol as a form of Vitamin E. Since tocotrienols are a form of Vitamin E found less abundantly in nature than tocopherols, the research on this super anti-oxidant is still recent and ongoing. It is predicted that tocotrienols will become recognized as the new super anti-oxidant in the very near future. Virgin Palm Oil is one of your best sources for Vitamin E. Most Vitamin E supplements and skin care products on the market today are soy-based.

In nature, there are approximately 600 known carotenoids, ranging from yellow orange to red hues and some 50 of these pigments possess Vitamin A activity of varying degrees. Virgin Palm Oil is one of the richest natural plant sources of carotenoids with concentration of 500–700 ppm. It has 15 times more carotenoids than carrots and 300 times more than tomatoes. No other vegetable oil contains carotenoids in such significant quantities. Analysis shows that alpha and beta carotenes constitute approximately 90% of the total carotenoid content.

Note: Vitamin A in its complete form is only available from fats in animal sources, like our cod olive oil. Carotenes are what our bodies (if they are functioning properly) use to convert to Vitamin A. While animal sources are a more readily available source of Vitamin A, Vitamin A can be toxic at excessive levels, whereas carotenes are not. Therefore, Vitamin A toxic levels are not possible from consuming Virgin Palm Oil.

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# HOW TO IMPROVE SAFETY AND NUTRITIONAL SECURITY OF RAW INGREDIENTS: THE CASE OF SORGHUM

Ilaria Proietti

*Department of Veterinary Public Health and Food Safety, Istituto Superiore di Sanità, Italy*

## Introduction

For years advancing technology allowed to raise land productivity all around the world. As a consequence, since 1950 the world as a whole has nearly tripled land productivity (1). Unfortunately, the steady growth of productivity is coming to an end while, on the other hand, the world population has been growing exponentially. As a result, and due to recent changes in the environment, food demand is more and more difficult to be met and one of major challenges facing the world is to meet the nutritional needs of more vulnerable groups. In order to meet the enhancing food requirement, innovative and sustainable measures are needed.

It is believed that the issues of food and nutrition security and health in developing countries can be addressed relying on indigenous crops (2). Indeed, with a soaring food crisis and changing weather patterns, the need to diversify the crop production to other less common varieties, such as local and indigenous crops like millets and sorghum, is real. Sorghum is one of the main traditional crops grown in numerous developing countries; it is a basic staple food for many rural communities, especially in drought prone areas of Africa, where it represents an important subsistence crop for many households. Sorghum has an important role in mitigating food insecurity, in particular of the low-income groups, which are the most affected by the lack of food and nutritional security, as it is widespread, nutritious, easy to grow and well adapted to local climate.

On the other hand, the nutritional value of sorghum is affected by inherent factors influencing its utilization, including Anti-Nutritional Factors (ANFs), able to bind proteins and divalent cations and interfere with their absorption, and mycotoxins, fungi secondary metabolites with adverse health effect on human health. Nevertheless, specific pre- and post-harvesting good practices and adequate food processing can be implemented in order to decrease the amount and activity of ANFs and mycotoxins and improve the food and nutritional quality of sorghum.

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## Nutritive and anti-nutritive properties of sorghum

Sorghum is the fifth most important cereal corn grown in the world agricultural economy after wheat, rice and barley. It is mainly grown in semi-arid areas of the world, characterized by high drought and low rainfall, climate conditions poorly favourable to the production of other cultivars. In industrialized countries, sorghum is mainly grown for the production of animal feed (forage or grain) or biofuel and more recently, for the lack of gluten content, it has been proposed as suitable food for coeliac people. On the other hand, in Africa, Asia and more recently in Latin America, sorghum production has increase steadily and is grown primarily for

human consumption. Only Africa produces around 20 million tons of sorghum per year, a third of the world total (2).

It is estimated that sorghum is part of the staple diet of more than 500 million people in more than 30 countries of the semi arid tropics, representing a major source of energy and nutrients (2). The sorghum kernel contains about 70% carbohydrate and 12% protein – similar content to that of wheat and maize - but the grain has more vitamin B than maize (2). Indeed, sorghum has a good content of protein and vitamins, mainly those of B group (except for B12) and fat-soluble vitamins (A, D, E and K), compared to other cereals. In addition, it is considered an important source of minerals, as it is rich in phosphorus, potassium, iron and zinc.

The nutritional value of sorghum is, nevertheless, impaired by the activity of endogenous factors, namely ANFs, such as phenolic compounds (mainly condensed tannins) and phytic acid, and mycotoxins. From an agronomical point of view, the presence of ANFs is associated with diminished pre- and post-harvest losses due to bird predation and storage pests, respectively. On the other hand, these sorghum ANFs interact negatively with the bioaccessibility of essential elements, in particular iron and zinc, and the digestibility of proteins. The general mechanism involves the formation of insoluble complexes at physiological pH, due to the ability of phytic acid and tannins to bind proteins and divalent cations. The concentration of tannins and phytic acid greatly varies among different cultivars, as well as among plants belonging to the same cultivar. The phytic acid concentration can range from 2.5 to 22 mg/g and that of tannins from 0.8 to 55 mg/g, expressed as catechin equivalent (4). This range in the amount depends on several factors, such as sorghum variety, growing conditions, harvesting techniques and processing methods. Moreover, it has been demonstrated that the diversity and severity of adverse effects of ANFs are greater in tropical than in temperate climates (5).

Phytic acid is the storage form of phosphorus bound to inositol in the fiber of raw whole grain. It accounts for 50-80% of the total phosphorus (6). Although sorghum is relatively rich in phosphorus, phytate-phosphorus is less nutritionally available since the phytate is not quantitatively hydrolyzable in human gut (7). Another ability of phytic acid is to form binary protein-phytate complexes under acidic pH conditions (8) and the effects of this interaction can be detrimental for malnourished people. Also tannins have the ability to interact with proteins and complex a substantial proportion of them (9,10). It has been demonstrated that an amount of tannins of 1.9 g/kg is able to reduce real ileal digestibility of 16 aminoacids by nearly 9.8% in pigs, while 13.6 g/kg of phytate can reduce apparent ileal digestibility of 18 aminoacids by around 3.6% (11). Tannins and phytic acid are also able to bind enzymes in the gastrointestinal tract, thereby inhibiting their activity: glucosidase activity,  $\alpha$ -amylase, trypsin and lipase activity (12-14).

Furthermore, sorghum, so as many other cereal plants, may be infected with mycotoxin producing fungi at all levels of the food chain: from production to processing and also in the supply chain. Mycotoxins represent one of the heaviest burdens, particularly for developing countries, both in terms of health implications and economic losses. Among the several mycotoxins, aflatoxins and fumonisins produced by *Aspergillus* and *Fusarium*, respectively, are a major problem in sorghum grains. Mycotoxins are potent carcinogens and can interfere with the immune system functioning and the normal human homeostasis. Moreover, mycotoxins or its metabolites pass into milk, eggs and other organs when animals are fed with contaminated grain, thus entering the food chain. The ingestion may be critical especially in vulnerable and weakened human bodies. For example, children exposed to aflatoxin may become stunted, underweight and more susceptible to infections. A study in West Africa shows a strong correlation among stunted growth in children and exposure to aflatoxin (15). Hendrickse states that the mycotoxins cause kwashiorkor by damaging the liver, which becomes unable to produce albumin and low levels of the protein lead to the disease (16).

## Effective practices for reducing the amount/activity of adverse endogenous factors

Factors enhancing the likelihood of ANFs and mycotoxins are numerous and include extreme environmental conditions, inadequate practices and the absence of adequate monitoring and control system (17). As a consequence, a number of preventive and corrective measures able to reduce the risk of ANFs and/or mycotoxins in sorghum grains exist.

The available literature (18-20) reports that food preparation and/or processing influence ANF content and activity. In particular, wet processing (including soaking, germination and fermentation) leads to a decrease of phytic acid and increase of solubility of minerals in foods. A study by Mahgoub and Elhag states that the soaking of sorghum flour at room temperature reduces phytic acid by 16-21%, germination for four days by 68-87%, while accelerated fermentation by 60% (21). Decreased content of phytic acid and tannins after fermentation or germination is mostly due to the activity of enzymes, while in soaking to a combination of diffusion and enzymatic action (21-24). Many authors state, in particular, that enzymatic hydrolysis of phytic acid during fermentation is caused both by endogenous and microbial phytase (mainly lactic acid bacteria phytase) (24-26). Another practical and effective process able to reduce tannins in sorghum grain is the treatment with wood-ash slurry. The action is probably caused by its alkali content able to detoxify tannins (27).

While for the reduction of ANF risk adequate post-harvesting practices are required, for mycotoxins control, both good pre- and post- harvesting practices are needed. Prevention is the best practice to improve the safety of vegetable and animal product from mycotoxins contamination. Adequate good practices should be applied in every phase of the food chain: harvesting, processing, storage and distribution in order to carry out an ideal integrated risk management. Examples of pre-harvest measures include the selection of cultivars less susceptible to grain moulds and good crop management practices, such as crop rotation and right harvesting time (28); while, post-harvesting practices include the good management practices in order to avoid grain damage during threshing and from insect damage during storage, the selection of not mouldy and damaged panicles, the use of certain feed additives like toxin adsorbents (28, 29). More recently, different physical and chemical methods have been proposed for their ability of detoxifying mycotoxins from food constituents. Biotechnological methods based on microbial fermentation, to detoxify contaminated grains, or addition of binding agents such as bentonite clay, aluminosilicates, activated charcoal and bacteria, to absorb the mycotoxins, have been investigated (30,31). Mycotoxin binders represent an attractive short-term solution to the challenge of mycotoxin-contaminated food, while a better solution would be the achievement of improved quality control and good practices.

In conclusion, an adequate combination of good pre- and post-harvest practices are the successful strategy for minimizing the risk of adverse endogenous factors, such as ANFs and mycotoxins and improve the safety and nutritional quality of sorghum.

## Conclusion

Given the important role of sorghum in the diet as a source of both macro- and micronutrients for many low-income people, an improvement of its safety and nutritional quality is needed. Moreover, because of its ample utilization both as feed and, more recently, as food, such improvement would have positive consequences also for more developed countries.

Sorghum grains offer a good nutritional value which is, nevertheless, partially impaired by the activity of inherent adverse factors such as ANFs and mycotoxins. In order to reduce their content and/or activities, and so increase the bioavailability of proteins and zinc and iron, a number of measures are available. The most effective ones are the implementation of good practices throughout the food chain. Good practices are applicable both in pre- and post-harvest phase and allow preventing and / or minimizing the risk of adverse endogenous factors activity. In this regard, it is necessary to assess and control, along the sorghum production chain, the phases considered critical for ANFs and mycotoxins. Only with an integrated assessment and management of risks the improvement of nutritional value of sorghum could be possible.

In addition, through cheap and easy to use methods the content and/or activity of ANFs can be drastically reduced and its nutritional quality improved. As the sorghum is mainly used as staple food in developing countries, its improved quality would allow reducing the risks for more vulnerable population groups, such as the infants (as sorghum porridge is largely used as weaning food), pregnant women and, more in general, undernourished people. The safety assessment of sorghum products has an important value especially for pregnant women, in order to «*minimize also adverse health impact on future generation*», according to the “sustainable food safety” approach (32).

In conclusion, the enhanced food safety and nutritional quality of sorghum will have a valuable impact also for the food security. Moreover, it is important to raise awareness of the sorghum as valuable indigenous crop and spread the optimal food management and processes, with the aim of combating food shortages and also revitalize local culinary traditions.

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# CAMEROONIAN COOKING METHODS, INGREDIENTS, RECIPES AND DIET, AND THEIR RELAPING ON PREVENTION OF DISEASE BURDEN

Elie Fokou, Mercy B. Achu  
Faculty of Science, University of Yaoundé I, Cameroon

## Introduction

Foods are consumed for their organoleptic properties, their nutritive value and ability to stop hunger. Good feeding, especially with poverty, is characterized by diverse plant food sources. Unfortunately, this diversity which enables coverage of nutritional needs, is also a risk factor for the ingestion of substances harmful to the use of digested foods (antinutrients) or harmful to the biology and physiology of the system (toxic substances).

Old eating and cooking habits have enabled groups of people to look for a balance between their survival and health on the one hand and between their biological and environmental resources on the other hand. For example, in the traditional society only sweet cassava was consumed as food, whether raw or boiled. The bitter variety was only used for the preparation of cassava paste balls (*bobolo*) or *fufu* flour after fermentation and elimination of the toxic juice, which is rich in cyanhydric acid. This treatment lasted for at least one week. In today's modern society, the duration of treatment is becoming shorter and shorter, without the assurance that the toxic substances are eliminated. The bitter cassava variety is at times directly put into the pot, because of poverty, since the sweet variety is more expensive. Another example is that of *ndolé* (*Vernonia amygdalina*), which contains bitter saponins, where washing with water eliminates a greater quantity of them. In the past, *ndolé* was usually washed until the bitterness disappeared when tasted. Nowadays, under the pretext that much washing leads to the loss of hydrosoluble vitamins and minerals, people wash *ndolé* without paying any more attention to the elimination of toxic substances. It therefore appears that the diversity of foodstuffs, recipes and especially cooking methods are the key determinants of the levels of antinutrients, toxins and nutritive substances in food as it is eaten. This diversity is understood, not only in its biological nature, but also from the point of view of its agricultural itinerary, the agro ecological environment, the production and conditions of preservation which, if not well controlled, are favourable to the development of molds, which secret mycotoxins.

In this chapter, we are just going to give a summary presentation of the diversity of foodstuffs in Cameroon, cooking recipes and the main dishes of the different regions in Cameroon, as a prelude to a future work analysing the toxicological risks associated with the different cooking practices in the Cameroonian context.

## Ingredients

Studies done within the framework of elaborating a national strategy for the development of the rural sector in Cameroon revealed and projected food needs as indicated in Table 1 (1).

**Table 1. Projection of food needs\* in Cameroon from 1985 to 2020**

Products/year	1985	1995	2010	2020
Cereals	1070	1465	2322	2801
Starchy foods	2026	2775	4396	5303
Legumes	389	533	844	1018
Fruits and vegetables	508	696	1102	1330
Vegetable oils	147	201	319	385
Sugar	75	103	163	196
Meat	352	483	764	921
Total	4421	6057	9592	11572

\*Thousands of tons.

Most farmers are engaged in a large number of food crops, where 72% cultivate corn, 71% peanuts, 58% cocoyam (*taro*), 56% plantain, 53% bean or cowpea, 52% vegetable crops. About 70% of food crops are consumed and only 30% are marketed. About 80% of food needs are produced in the country and 20%, mainly cereals, are imported. Cereals, tubers and pulses are the crops that occupy the largest areas of cultivation. There is a low use of inputs, which explains the low yields (2 tons/ha for maize, 12 for cassava, 14 for plantain, 0.8 for peanuts). Corn production is estimated at 750,000 tons/year. Cameroon imports 30 to 35,000 tons to meet the demands of domestic brewing and animal feeding industries. The production of potatoes has doubled since the 1990s and is rising to about 160,000 tons / year with a yield of 20 tons / ha. The demand for rice in the domestic market is about 200,000 tons, but the national production of paddy rice is only about 60,000 tons. Onion is produced mainly in the northern regions of Cameroon and much of it is exported. Approximately 4000 tons of pineapples are exported annually.

Livestock production provides the main source of income for 30% of the active population. The national herd is estimated at 5.6 million cattle, 7 for small ruminants, 1.2 for pigs, 31 for poultry and 15,000 for horses. Cattle breeding provides 110,000 tons of meat and 184,000 tons of milk annually. For an annual consumption of 13.07 kg of meat products, 7.11 kg comes from cattle, which is about 54% of the consumption. Fish production is estimated at 173,000 tons, including 93,000 tons from small scale fisheries, 75,000 tons from inland fisheries and 5000 tons from aquaculture. The annual needs of the population are around 298,000 tons. These data sufficiently show that Cameroonian foodstuffs are diversified and are mainly produced traditionally, with low use of fertilizers and pesticides. These agricultural practices, although inappropriate for yields to meet up with food security, provide toxicologically more advantageous foodstuffs.

There is also a variety of fruits, most of which are seasonal, like mangoes, avocados, papayas, guavas, pineapples, plums; citrus fruits like oranges, grapes, lemon and lime. The foodstuffs produced do not have a homogeneous distribution on the national territory. Considering the difficulties in food distribution and food habits, there are generally two main areas of distribution of foodstuffs: the northern and southern regions of Cameroon.

Staple foods from the northern regions of Cameroon include millet, rice, yam and sweet potatoes as starch sources. Vegetables include *folefé*, baobab, amaranthus leaves and onions. Fruits include oranges (imported mainly from Nigeria), mangoes, nuts (*noisettes*). Cotton oil is the main kitchen oil. The main sources of animal proteins are beef, sheep and milk. Food security in this region is not stable due to many environmental hazards like poor rainfall and pests. In the southern part of the country, the sources of starchy foods are divers: maize, cassava tubers, cocoyam (*macabo*), potatoes, green bananas and yams.



## Recipes

Cameroon is known for having some of the best foods in Central Africa. This diversity is reflected in the Cameroonian cuisine which is based on a blend of exotic spices, giving the food its unforgettable taste. The cuisine of Cameroon is one of the most varied in Africa, added to the influence of French food, a legacy of the colonial era. There are many national dishes in Cameroon. One of the most common is *ndolé*, a spicy stew consisting of bitter leaves, shrimps, peanut paste and fish or meat. There is also bread, Italian pasta and European desserts. Sauces are usually accompanied by rice or a thick mashed potato-like paste called *fufu*, which can be made from rice, corn, cassava, plantains or bananas, cocoyams (taro and macabo). These sauces can also be consumed with these boiled compliments.

In the larger cities, however, such as Douala and Yaoundé, there are many restaurants offering a wide variety of Western dishes, as well as Chinese and Indian food. There are also numerous burger bars serving American-style fast food (2).

The 10 regions of Cameroon (Adamawa, Centre, East, Far-North, Littoral, North, North-West, West, South and South-West) have many ethnic groups, each with its own culture and cuisine (3).

### Dishes of the Centre, South and East Regions

In the Centre and South regions, plantain is considered as the staple food of the populations. Maize is also very popular, followed by rice. These regions are particularly characterized by certain dishes like *kwem* (young cassava leaves with the juice from palm nuts), *nnam ngon* (Cucurbit seed paste cooked in plantain leaves), *nnam owondo* (a dish made from shrimps, peanut paste and pepper) and *ndomba tsit* (meat cooked tied in plantain leaves), *sangah* (a mixture of maize, cassava leaf and palm nut juice) (4).

### Dishes of the North, Far-North and Adamawa Regions

While tuber crops and plantains are staple foods in the southern part, cereals (millet and corn) and peanuts are the staples in the northern parts. Maize is consumed almost everywhere, especially in the western part of Adamawa. In the North, Far-North and Adamawa regions, the most commonly eaten meat is beef, from the herds which make up the wealth of North Cameroon. The people that inhabit the northern regions also eat insects (termites, the karite caterpillars and others) and small hunting products: birds, field mice, squirrels, rats and frogs (3).

### Dishes of the Littoral Region

The dishes here consist mostly of cocoyams, cassava, beans, Colocasia leaves, grains and nuts. These vegetables are cultivated. There are many ethnic groups inhabiting this region, each with its own culture and traditional cuisine. For example, the Bassas and Bakokos' traditional dish is palm nut (*mbanga*) soup with fish or meat, eaten with cooked cassava rolls (*munyondoh*). The Douala tribe prefers the bitterleaf soup, cooked with squash grains (*egusi seeds*) or peanuts and eaten with boiled plantains. The regional dish of the Littoral region is *ekoki*. The ingredients for this dish include the Vigna beans variety and the Voandzou (*matobo*) grains. This dish is

served with plantains, cocoyams or *taro*. Another dish of this region is the yellow soup served with cocoyams (3, 5).

## Dishes of the West, South West and North West Regions

*Fufu* made from corn or cassava is the staple food of these regions. Other important staple foodstuffs in these regions are tubers like yams, cocoyams, cassava and sweet potatoes (5). Tubers and bananas are quite often cooked in a mixture with a variety of meats (goat, sheep, pork, beef, chicken and bush meat). These mixtures are called *kondre*. Pounded *taro* is also prepared and eaten with yellow soup. There are many leaves used as vegetables in this cuisine. Some of them are cocoyam (*taro* and *macabo*), cassava, bean and huckle berry leaves. The usual cooking method for these leaves is mixing them with red palm oil and seasoning with salt, maggi cube and pepper. In some parts of the West regions, people eat more exotic dishes, like the flesh of dog, cats and some snakes. The larvae of certain insects are also considered delicacies. There are specific sauces in the West, such as *nkui*. Peanut sauce cooked with fish or meat is also common (3). Water *fufu* and *eru* (fermented cassava paste consumed with a green vegetable source made up of leaves of *Gnetum africanum*, waterleaves and red palm oil) is peculiar to the South-West and North-West Regions.

## Cooking methods

In Cameroon, most families have mud stoves outside their homes for cooking and because smoked fish is such a vital part of the diet, most homes also have a smoking stove (5).

In rural Cameroon, the fuels used for cooking are firewood, charcoal, kerosene stoves and crop residues (5). In the urban areas, gas cookers are commonly used. The cooking methods consist mostly of frying, boiling and steaming and roasting, according to the taste desired.

## Cameroonian foods and prevention of disease burden

Most Cameroonian foods, ingredients and spices are functional foods, providing health benefits beyond the traditional nutrients they contain, especially foods of plant origin. Previous studies indicate that a plant-based diet can reduce the risk of chronic disease, particularly cancer. Cancer risk in people consuming diets high in fruits and vegetables was only one-half than in those consuming few of these foods (6). Examples of some Cameroonian functional foods include:

- *Soybean*. It is mostly used in Cameroon for thickening sauces and the flour is usually added to weaning foods. Soybean besides its high quality protein, as assessed by the FDA's "Protein Digestibility Corrected Amino Acid Score" method, is now thought to play preventive and therapeutic roles in Cardiovascular Disease (CVD), cancer, osteoporosis, and the alleviation of menopausal symptoms (7).
- *Tomatoes*. In Cameroon, it is used in stews and salads and most sauces. It is rich in lycopene, the primary carotenoid found in this fruit and it is important in cancer risk reduction.
- *Garlic*. It is used as a spice in most traditional dishes and sauces in Cameroon. The health benefits of garlic are numerous, including cancer chemopreventive, antibiotic, anti-hypertensive, and cholesterol-lowering properties (8).

- *Onion*. Like garlic, it is also used as a spice in Cameroon, and it plays an important role in reducing blood pressure.
- *Citrus fruits*. In Cameroon, these fruits are mostly consumed by sucking out the juice directly from the fresh fruits (oranges, grapes, tangerines). The juice from lemons and limes are usually used to prepare other fruit juices. Several epidemiological studies have shown that citrus fruits are protective against a variety of human cancers (9).
- *Tea*. Tea is produced in some parts of Cameroon like the North West (Ndu) and South West regions (Tolé) and consumed in Cameroon. Polyphenols comprise up to 30% of the total dry weight of fresh tea leaves. There is some evidence that tea consumption may also reduce the risk of CVD.
- *Dairy products*. Milk and its products like yoghurt are produced and consumed in Cameroon. Dairy products are one of the best sources of calcium, an essential nutrient which can prevent osteoporosis and possibly colon cancer (7).

The various properties of foods beneficial to health may be reduced by the presence of anti-nutrients and toxic substances. In perspective, it would be interesting to undertake a case study on the toxicological risks linked to recipes and cooking methods of the different regions of Cameroon.

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# DIETARY EXPOSURE TO PESTICIDE RESIDUES, MINERALS AND HEAVY METALS: THE CAMEROONIAN TOTAL DIET STUDIES

Marie Madeleine Gimou

*Service of Hygiene and Environment, Centre Pasteur of Cameroon*

## Introduction

The need for monitoring chemicals in the food supply is essential as consumers are unable to know to which toxic chemicals and nutritional imbalances they are exposed through the foods they consume. Toxic chemicals may affect all major organs in the body, causing serious health outcomes like cancer, birth defects, reproductive disorders, kidney and liver dysfunction, hormonal imbalance, immune system suppression, musculoskeletal disease, cardiovascular diseases, and brain damage. Contamination of food may occur through environmental pollution of the air, water and soil, such as the case with toxic metals, PCBs (PolyChloroBiphenyls) and dioxins, naturally occurring toxicants, or through the intentional use of various chemicals, such as pesticides, animal drugs and food additives.

While monitoring for compliance with regulatory standards is essential for consumer protection and facilitation of trade, governments need to assess public health risks arising from the presence of toxic chemicals in foods, by estimating the actual dietary exposure of contaminants for comparison with their corresponding toxicological reference intakes. Thus, estimating the dietary exposure of contaminants is indispensable for risk assessment and can also be used in determining whether there may be a relationship between observed adverse effects in humans and exposure to a particular contaminant. Contaminant exposure assessments are equally critical for making sound decisions in the regulation of chemicals and food safety.

The Agreement on the Application of Sanitary and Phytosanitary Measures of the World Trade Organization (WTO) requires that health and safety requirements related to food must be based on sound scientific risk assessment. Dietary exposure estimates are also used in developing standards, guidelines and other recommendations at national and international level, including in the context of the *Codex Alimentarius* Commission. Finally, dietary exposure estimates can provide assurance that regulatory systems that have been established are effective in protecting the public health.

The World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO) promote the use of Total Diet Studies (TDS) as one of the most cost-effective methods to monitor the potential health impact of chemicals in the food supply. WHO also recommends the implementation of TDS in developing countries and encourages the inter-country collaborations, to ensure safe food supply and adequate nutritional diet (1).

The first African TDS was conducted in Cameroon. This chapter summarizes the activities implemented with results currently available and perspectives in sub-Saharan Africa. This was made possible with financial and technical support of FAO, WHO, Standards and Trade Development Facility/World Trade Organization (STDF/WTO), French National Institute for Agricultural Research (INRA), French Food Safety Agency (AFSSA), and Laboratories Qualtech, LERQAP and Centre Pasteur of Cameroon.

## Design of the total diet study

The design of a TDS includes (i) building from a food consumption data, a list of food to be analyzed that constitutes a large part of the total diet of the study population, (ii) purchasing these food, preparing them “as consumed” by the study population; aggregating them into composite samples prior to analysis for selected chemicals, (iii) combining food consumption and contamination data obtained, in order to evaluate a distribution of contaminant intakes within the population. This distribution is then compared to international reference values to assess the safety of food consumed by the population.

## Dietary exposure to pesticide residues in Yaoundé

In 2006, the chronic dietary exposure of the inhabitants from Yaoundé/Cameroon to 46 pesticides residues was assessed according to the TDS approach. The 2001 Cameroonian Household Budget Survey was used to derive the food consumption data needed for the TDS. Sixty-three composite samples, representative of 93% of the diet were purchased, prepared as consumed and analyzed. Multi-residue gas chromatography methods, using specific detectors and based on the European standard NF EN 12393, were applied for 43 pesticide residues. The Limit Of Detection (LOD) was equal to 0.005mg/kg and the Limit Of Quantification (LOQ) equal to 0.010 mg/kg. Additional analyses were performed for dithiocarbamates (spectrophotometric method: LOD = 0.050 mg/kg and LOQ = 0.100 mg/kg), glyphosate (liquid chromatography method LC-MS/MS: LOD=0.005 mg/kg and LOQ = 0.010 mg/kg), and chlordecone (Gas Chromatography method GC/ECD and GC/MS: LOD = 0.0008 mg/kg and LOQ = 0.0020 mg/kg), on certain composites samples. The results obtained showed that:

- a) The amount of foods as consumed without drinks, by individual with normal energy intake (1200-3500 kcal/day/adult equivalent), was estimated on average to be 863 g/day/adult equivalent. Cooked rice was by far the most consumed food with 201 g/day/adult equivalent, followed by boiled fresh cassava tubers (73 g/day/ adult equivalent), boiled unripe plantain (47 g/day/ adult equivalent), bread (47 g/day/ adult equivalent) and others foods.
- b) Out of the 46 pesticides analysed, only nine pesticides were detected, namely atrazine, chlorothalonil, cypermethrin, deltamethrin, endosulfan, malathion, pirimiphos-methyl, DTC and chlordecone. These pesticides were detected in nine of the 63 composite samples. These were the raw or cooked aromatic herbs, a composite of basil, parsley and celery (atrazine 0.02 mg/kg and DTC 8.66 mg/kg), boiled Ndole/Keleng Keleng which are local leaves (chlorothalonil 0.02 mg/kg and endosulfan <LOQ), raw and cooked fresh tomatoes (cypermethrin 0.05 mg/kg, endosulfan 0.02 mg/kg and Chlordecone 0.004 mg/kg), bread (deltamethrin <LOQ, malathion 0.05 mg/kg and pirimiphos-methyl 0.02 mg/kg), wheat doughnut (malathion 0.04 mg/kg and pirimiphos-methyl 0.02 mg/kg), cakes and pastries (malathion 0.05 mg/kg and pirimiphos-methyl <LOQ), boiled wheat pasta (pirimiphos-methyl <LOQ), pineapple (DTC <LOQ), papaya (DTC 0.14 mg/kg). No tested pesticide residue was detectable in drinking water.
- c) The highest dietary exposure estimate was 0.941-0.973  $\mu\text{g}/\text{kg}_{\text{bw}}/\text{day}$  at the 95<sup>th</sup> percentile of exposure to DTC, which is well below the ADI (Acceptable Daily Intake) of 30  $\mu\text{g}/\text{kg}_{\text{bw}}/\text{day}$  (2), equivalent to 3.24% of the ADI. For the pesticides for which at least one analysis was >LOD, the mean exposures using the “upper bound” estimate represent from

0.24% (cypermethrin) to 3.03% (pirimiphos methyl) of their respective ADIs. Using the 95<sup>th</sup> percentile (“upper bound” estimates), these relative proportions reached 0.42 and 5.14% of their ADIs, respectively.

In conclusion, the chronic dietary exposure to the various pesticides evaluated within the framework of this TDS was low for the inhabitants of Yaoundé. These results were reassuring and seemed to be in concordance with the opinions of the experts of the agricultural domain in Cameroon (3).

## **Dietary exposure to minerals, trace elements and heavy metals in Yaoundé**

In 2010, the dietary intake assessment of the same population (Yaoundé/Cameroon) to minerals, trace elements and toxic metals were carry out. Consumption data used were the same as in 2006 (4). The majority of composite food samples analyzed (48/64) were purchased and prepared in 2006 and then stored at -20°C. While the others composite samples (16/64) were purchased and prepared between February and March 2010.

The sixty four food composites representing an average of 93% (96.5% including prepared meals purchased outside the household) of the diet of the inhabitants of Yaoundé were analyzed by plasma mass spectrometry (ICP-MS) after microwave digestion, for the determination of 25 mineral elements.

These elements include minerals and trace elements (Li, Ca, Mg, Na, K, Fe, Co, Cr, Cu, Mn, Mo, Ni, Se, Zn, V), toxic metals (Al, As, Ba, Cd, Ge, Hg, Pb, Sb, Sr, Te). The limit of quantification (LOQ) ranged between 5-25 mg/kg for major elements and 0,002-0,417 mg/kg for trace elements. The limit of detection (LOD) was half the LOQ for each element.

The expected results for individual with normal energy intake include (i) concentrations of minerals found in food “as consumed”, (ii) the average estimate exposure with percentiles, (iii) strong contributors to food exposure, finally (iv) a comparison of the 2.5<sup>th</sup> and 97.5<sup>th</sup> percentiles of the exposed population with nutritional or toxicological reference values in order to assess the nutritional or the safety of food consumed. These results are currently being analyzed.

## **Perspectives in sub-Saharan Africa**

In March 2010, Centre Pasteur of Cameroon in collaboration with the WHO, FAO, INRA organized a Total Diet Study training workshop, funded by the STDF/WTO for sub-Saharan Africa. Over 14 participants from Burkina Faso, Cameroon, Mali, Nigeria, Senegal attended the workshop. This course included consideration of regional adaptations to the WHO recommendations concerning TDS and elaboration of a TDS project at a regional level. The project proposal is to be submitted to STDF/WTO for funding. This challenging process will lead to a better understanding of the chronic dietary exposure of the sub-Saharan population to toxic chemicals, and associated potential health risks, and the ability to more effectively manage and communicate such risks.

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# CONTAMINATION OF HERBAL SUPPLEMENTS AND PEDIATRIC SYRUPS: NIGERIA CASE STUDY

Orish Ebere Orisakwe  
Faculty of Pharmacy, University of Port Harcourt, Nigeria

## Introduction

The use of traditional and alternative medicine has increased worldwide (1-7). However, the safety of alternative medicinal preparations for use has been questioned due to reports of unwanted side effects (8-14). There have been reports of acute and chronic intoxications resulting from their use (15). The popularity and availability of these supplements have generated concerns regarding the safety, efficacy and responsibility of practitioners using these supplements (16). A common misperception is that medicaments of natural origin are not harmful or dangerous. Contrary to this belief, naturally occurring substances are some of the most toxic and hazardous substances can be present in toxic concentrations in a variety of herbal preparations and dietary supplements (17). Some Asian herbal remedies contain synthetic pharmaceuticals: antihistamines, aromatics, steroids, alkaloids and other adulterants suspected to have caused illness in some patients (18). Heavy metals are a known contaminant or adulterant of many Asian remedies (15). In a random sampling of Asian remedies conducted by Garvey *et al.*, 2001 (15), they discovered that the Asian remedies evaluated contained levels of arsenic, lead and mercury that ranged from toxic (40%) to those exceeding public health guidelines for prevention of illness (74%) when consumed according to the directions given in or on the package. Indian traditional remedies have been reported to be contaminated with significant amounts of lead, mercury, arsenic and cadmium (19). Traditional Chinese medicines have been reported to be contaminated with heavy metals especially lead (20).

The downturn in the Nigerian economy in the early 1980s heightened the use of herbal remedies. Even with the efforts made by the government to provide a meaningful health care has not discouraged the people from seeing herbal medication as a popular choice. This resurgence or undying interest has prompted the National Agency of Food Drug Administration Control (NAFDAC) to enforce a regulation of the manufacture, sale and use of herbal remedies in Nigeria. Some studies aimed at investigating the presence of cadmium, antimony, tin, mercury, cobalt, copper, iron, nickel, selenium, zinc, and lead in some Nigerian herbal remedies and to examine the public health risks associated with them have been carried out.

The presence of all these heavy metals in these Nigeria herbal remedies is of public health importance. As reported in Table 1, Ghana black stone contained the highest level of lead (27,000 µg), whereas Aloe Vera plus Bitter aloes contain the lowest (250 µg). Only one sample (Aloe Vera plus Bitter aloes) contained high level of mercury (60 µg) in twenty five samples (21).

Aloe Vera plus Bitter aloes contained the highest level of cadmium (3375 µg) whereas U & DEE infection cleansing powder contains the lowest level (550 µg). The cadmium levels range from 550 µg to 3375. Ghana Black stone contain the highest level of nickel (78,000 µg).

The MPL of nickel is 100 µg/day (22). In the study carried by the Orisakwe group, 100% of the tested supplements contained higher level of nickel greater than the maximum permissible level. Nickel is a widely used heavy metal, which exert a potent toxic effect on peripheral tissues as well as on the reproductive system (22).



**Table 1. Lead, mercury, cadmium and nickel levels ( $\mu\text{g}$ ) in some Nigerian herbal supplements**

Nigerian herbal supplements	Cadmium	Lead	Mercury	Nickel
B-success 28 plant	1150	4200	31	8650
Operation sweep	1025	2025	12	5000
Aloe vera plus bitter aloes	3375	250	60	14,125
Zarausmacine	1175	2100	13	6325
Virgy-virgy computer worm expeller	900	1550	18	4700
Dorasine powder	775	1375	23	4025
Sexual energy	950	1600	21	5975
U & dee infection cleansing powder	550	925	18	2525
U & dee sweet bitter	1750	3600	9	12275
Natural powder stone	4750	9125	4	18,000
Ghana black soap	1325	27,000	23	78,000
Portugal antiseptic soap	1975	4200	17	11,875
Edysol antiseptic soap	1000	1925	11	5575
H-nal	1000	1925	7	4275
M-reg	950	1825	14	4500
Veins flusher	1650	1100	4	3325
Diabor	250	2500	16	6600
C-candi	2050	4275	7	11,775
C-cystra	3375	1200	18	15,750
Firas	1075	1975	21	6350
D-diab	700	1200	30	3025
P-pile	2875	4750	6	13,000
Infecta	600	1075	2	2750
Rinbacin forte	750	1375	11	3800
Aloe vera cure formula	700	1100	23	3075

In 1989, the Food and Agricultural Organization/World Health Organization Joint Expert Committee (FAO/WHO) on Food Additives set the Provisional Tolerable Weekly Intake (PTWI) for cadmium at  $7 \mu\text{g}/\text{kg}_{\text{bw}}/\text{week}$  corresponding to  $1 \mu\text{g}/\text{kg}_{\text{bw}}/\text{day}$  or  $70 \mu\text{g}/\text{day}$  (WHO, 1989) (23). In the same study, the lowest level of cadmium was  $550 \mu\text{g}/\text{day}$  while the highest level was  $4,750 \mu\text{g}/\text{day}$  indicating that all the tested remedies contained high level of cadmium.

The lead level ranged from 250 to  $27,000 \mu\text{g}/\text{day}$  (21). These concentrations are higher than the PTWI of lead established by FAO/WHO. This portrays a great danger to the Nigerian public. In a similar study conducted by Garvey *et al.* (2001) with Asian herbal remedies, 60% of the medicaments tested gave a daily dose of lead in excess of  $300 \mu\text{g}$  per day, whereas in the Obi and colleagues study (21), 96% of the supplements tested gave a daily dose of lead in excess of  $514 \mu\text{g}$  per day.

The joint FAO/WHO Expert Committee on Food Additives (1972) (24) provisionally recommends total mercury intake should not exceed  $5 \mu\text{g}/\text{kg}_{\text{bw}}$  per week with not more than  $3.3 \mu\text{g}/\text{kg}$  per week as methylmercury. We have shown from the present study that 88% of the tested remedies have a mercury level greater than the PTWI of mercury as recommended by the FAO/WHO.

The metal constituents of these Nigeria herbal supplements may be the silent etiological agents of a variety of ailments. Several possibilities exist to explain the presence of heavy metals in herbal supplements. First heavy metals could be included intentionally for alleged medicinal properties. Second, the presence of heavy metal may be the result of accidental contamination during manufacture, for instance, from grinding weights or lead-releasing containers or other manufacturing utensils (25). Third, medicinal herbs may contain heavy metals when grown in seriously polluted soil (26). In this context, it is relevant to know that herbal supplements may also

contain animal and mineral products which may also be contaminated with heavy metals (27). Therefore, a critical evaluation of their safety for use is extremely important (4, 14). The general belief that herbal preparations are natural and, therefore, inherently safe (28, 29) harmless and without any adverse effects is sometimes unfounded (30).

However, these metals are usually not identified as being present or associated with traditional and herbal supplements. The clinical identification of metal toxicity is unlikely during a clinical evaluation, especially if the patient hide the use of traditional and herbal supplements because of perceived embarrassment. Therefore, physician awareness of these potential sources of heavy metal is essential when diagnosing conditions of uncertain etiology that have similarities to metal toxicity.

Taken together, studies so far revealed that most of the Nigerian herbal remedies contained elevated amounts of heavy metals. These findings may be timely alert of the possibility of heavy metal toxicity from Nigerian herbal remedies. The clinical identification of metal toxicity is unlikely during a clinical evaluation, especially if the patient hide the use of traditional and herbal supplements because of perceived embarrassment. Therefore, physician awareness of those potential sources of heavy metal is essential when diagnosing conditions of uncertain etiology that have similarities to metal toxicity. For protection of public health, consumers taking this medication should be warned of potential toxicities and it is important that physicians and regulators are aware of these risks and find ways to minimize them.

## **Heavy metal contamination of pediatric syrups**

The health effects of chemical contaminants in consumables are a major health concern today. A very vulnerable and sensitive time in human development is in the womb and during the first five years of infancy. Unfortunately, it is during this time that we take between 70 and 80% of the toxicants accumulated by the body during our lifetimes (31). In a recent bio-monitoring survey of heavy metals levels in children aged 2-6 years in Nigeria by Nriagu and coworkers, many heavy metals ranging from chromium, nickel, manganese, including the traditional offenders like lead and cadmium to radioactive elements were found (32). Whereas the sources of the lead and cadmium are traceable to common matrices like food, water, air, etc., the sources of the other metals were a mystery.

In a prevalence study of parental medication on children before going to hospital performed by Orisakwe (33), 99% of children aged between 1-6 years were found to have received it before seeing a doctor. About 39% of the studied population had taken at least two drugs before been taken to the hospital. The most frequently administered drugs were paracetamol and chloroquine. Home treatment may be beneficial, but more often these drugs were taken concurrently or consecutively. Drug and non drug poisoning have been reported amongst children in Nigeria. Since there are no Poison Control centers in Nigeria, there are no standard therapeutic modalities in poison management. What exists is largely conservative management which employs all kinds of syrups in a poly-pharmacy manner in symptomatic management of poisoning even in the hospitals (34). These have led to high patronage of the pediatric syrups either by the parents or the hospitals.

Again in an attempt to have capture of the possible sources of heavy metals in children in Nigeria, Orisakwe and coworkers studies aimed at investigating the levels of heavy metals like in pediatric syrups commonly sold as over-the-counter drugs OTC have been an ongoing study.

The lead levels ranged from 0.01 in Gauze Chloroquine to 1.08 in Magcid Suspension. The highest level of cadmium was seen in Magcid Suspension with concentration of 2.45 mg/L while lowest concentration of 0.01 in Emzolyn and Colipan (Table 2). About 41.2% of the locally made syrup had none detectable levels of lead while all the syrup had detectable levels of cadmium (35).

**Table 2. Pb and Cd levels (mg/L) in pediatric syrups manufactured in Nigeria**

Pharmaceutical product	MFG Date	Expiry date	Metal level		Place of MFG
			Cd	Pb	
Asco –J vitamin	Aug 2007	Aug 2009	0.19	0.03	Enugu Nigeria
Emvite	Aug 2007	Aug 2010	0.33	0.41	Lagos Nigeria
J - Vite	Jul 2007	Jul 2009	0.22	0.14	Enugu Nigeria
Ferobin plus	Jun 2007	May 2010	0.05	0.09	Ogun Nigeria
Emzoklyn	May 2007	May 2010	0.01	0.17	Lagos Nigeria
Multivite	Jun 2007	Nov 2008	0.02	0.05	Ogun Nigeria
Kingsize Vit C	Jan 2006	Dec 2008	0.03	0.10	Ogidi, Nigeria
Asco-J Vit C	Aug 2007	Aug 2009	0.03	0.02	Enugu Nigeria
Gauze Vit C	Feb 2007	Feb 2009	0.02	nd	Awka Nigeria
Em-Vit C	Feb 2007	Feb 2009	0.02	nd	Lagos Nigeria
Zvobes cough syrup	Feb 2006	Feb 2009	0.03	nd	Lagos, Nigeria
Gauze multivitamin	Feb 2007	Feb 2009	0.07	nd	Awka, Nigeria
Gaviron	Feb 2007	Feb 2010	0.10	0.20	Awka Nigeria
Coflin	Sept 2007	Aug 2009	0.05	nd	Lagos Nigeria
Avipol	Jun 2007	May 2010	0.08	nd	Ogun Nigeria
Cypri Gold	Aug 2007	Jul 2009	0.02	nd	Lagos, Nigeria
Heamoglobin tonic	Jul 2007	Jul 2010	0.05	0.12	Lagos Nigeria
Emzoron tonic	Jul 2007	Jul 2009	0.06	0.15	Lagos Nigeria
Babyrex	Nov 2007	Oct 2010	0.34	nd	Ilorin Nigeria
Gauze chloroquine	Jan 2006	Feb 2009	0.41	0.01	Awka Nigeria
Septtrin Syrup	Oct 2006	Oct 2009	0.04	0.02	Ogun, Nigeria
Kp Multivitamin Syrup	Feb 2007	Jan 2009	0.63	0.96	Ogidi, Nigeria
Seven keys herbal mixture	Oct 2007	Oct 2010	0.64	0.12	Onitsha Nigeria
Phenergan	Jun 2006	Aug 2009	0.19	0.08	Lagos, Nigeria
Magcid suspension	Nov 2007	Nov 2009	2.45	1.08	Awka, Nigeria
Jawaron syrup	Jul 2007	Jun 2009	0.11	nd	Lagos, Nigeria
Diastop suspension	Jan 2007	Jan 2011	0.02	0.04	Lagos, Nigeria
Priton syrup	Oct 2007	Sept 2010	0.22	0.02	Ogun, Nigeria
2.2.1 forte chloroquine sulphate	Jan 2007	Dec 2010	0.07	nd	Lagos, Nigeria
Paracetamol syrup	Jan 2008	Jan 2011	0.07	nd	Lagos, Nigeria
Tixylix cough syrup	Sep 2006	Aug 2009	0.14	0.09	Lagos, Nigeria
Broncholyte	Dec 2007	Dec 2010	0.02	nd	Ogun, Nigeria
Colipan	Aug 2007	Aug 2010	0.01	nd	Ogun, Nigeria
EM-B-Plex	Jul 2007	Jul 2010	0.05	nd	Lagos, Nigeria

MFG: manufacturing; nd: not detected

Lead and cadmium levels in the syrups imported into Nigeria are shown in Table 3 (35). Lead levels ranged from 0.01 mg/L in Cadiphen manufactured in Dholka, India to 0.09 in Maxiquine made in England. About 68.8% of the imported syrups had non detectable levels of lead. Chloramphenicol and Zentel Albendazole syrups had 0.60 and 0.88 mg/L of cadmium respectively. Bellis Cough Syrup showed the lowest level (0.01 mg/L) of cadmium. Only Erythromycin Suspension representing 6.3% had non detectable level of cadmium of the imported syrups.

The results have shown the presence of lead in 60% and 98% cadmium of the sample size.

Cadmium absorption depends on the composition of the diet and the nutritional status of an individual. It has been shown that cadmium absorption as a percentage intake was inversely proportional to the individual's iron status (36, 37). Poor nutritional status of children in Nigeria will likely exacerbate lead and cadmium loading of children exposed to these syrups.

**Table 3. Pb and Cd levels (mg/L) in pediatric syrups imported into Nigeria**

Pharmaceutical product	MFG Date	Expiry date	Metal level		Place of MFG
			Cd	Pb	
Bellis cough syrup	Jun 2006	Jun 2009	0.01	nd	Southport, England
Mim iron syrup	Jun 2007	May 2010	0.05	nd	Mubai, India
Pentax paracetamol syrup	Oct 2006	Sep 2008	0.25	nd	Lagos Nigeria ( <i>licensed by Vitabiotic, England</i> )
Woodwards gripe water	Aug 2007	Aug 2010	0.15	nd	Lagos Nigeria ( <i>licensed by Woodward England</i> )
Menthodex cough syrup	Jun 2007	Jun 2010	0.14	nd	United Kingdom
Chloramphenicol	Oct 2007	Oct 2010	0.60	nd	Sango-Ota, Nigeria ( <i>licensed by Omega Mayor, Jersey</i> )
Erythromycin suspension	Nov 2005	Nov 2008	nd	nd	Bulchistan, Pakistan
Cephalexin syrup	Jan 2006	Jan 2009	0.10	nd	Cairo, Egypt
Vardorange syrup	Feb 2006	Jan 2009	0.08	0.02	Mumbai, India
Ailon multivitamin drop	Nov 2006	Oct 2008	0.12	0.03	London, England
Haemoglobin syrup	Feb 2006	Jan 2010	0.21	nd	Tipperart, Ireland
Halfan	Mar 2006	Mar 2009	0.48	nd	Nanterre, France
Zentel albendazole	Jan 2007	Dec 2009	0.88	0.03	Bangalore, India
Maxiquine	Jan 2007	Dec 2008	0.03	0.09	Lagos, Nigeria ( <i>licensed by Vitabiotic England</i> )
Piccan	Jul 2007	Jul 2010	0.09	nd	Dublin, Ireland
Cadiphen	May 2007	Apr 2011	0.55	0.01	Dholka, India

MFG: manufacturing; nd: not detected.

Although Blood Lead Level (BLL) < 10 mg/dL is currently considered as the threshold for concern in the United States (38), several studies suggest that there is no safe dose for lead exposure especially among children (39). BLLs below 10 mg/dL have been associated with impaired neuro-psychosocial development, delayed physical development and small stature, delayed onset of menarche and auditory problems (40).

In another study the highest levels of nickel were seen in Magcid suspension (4.13 mg/L) and Gaviron (0.79 mg/L) whereas lowest levels were found in Asco-J vitamin and Jawaron Syrup (0.01 mg/L). About 44.1, 73.6 and 20.6% of the sampled syrups made in Nigeria had non detectable levels of nickel, chromium and manganese respectively. Chromium levels ranged from 0.01 mg/L in Magcid suspension to 0.58 mg/L in emvite. Ferobin and Jawaron Syrup plus had 28.23 and 4.37 mg/L manganese, respectively (41) (Nduka and Orisakwe, 2009). With the exception of Cephalexin Syrup, all the imported syrups had non detectable levels of chromium. The level of chromium in Cephalexin Syrup was 0.01 mg/L. About 68.8 and 43.7% of these imported syrups had non-detectable levels of nickel and manganese respectively. Nickel levels ranged from 0.01-0.09 mg/L in the imported syrups. Haemoglobin Syrup showed highest level of manganese of 0.36 mg/L whereas the lowest concentration was 0.02 mg/L in Cadiphen. Taken together the Nigerian made syrup samples had higher concentrations of the studied heavy metals (41).

These studies were done with a view to lending credence to the assertion by Gidlow (2004) (42) that irrespective of the effort to reduce heavy metals exposure in the general population, legislation must be based on genuine scientific evaluation of the available evidence. The health effects of chemical contaminants in consumables are a major health concern today.

In Nigeria, it is common practice for doctors to recommend most of these drugs known to cure specific ailments (such as indigestion, headache, malaria, cough, measles, cold, catarrh, anaemia, stomach upset etc) to pregnant women and lactating mothers and children. A possible route of these metals into these drugs may be during processing such as lead solder, use of

contaminated water, poor assaying of raw materials, packaging, poor hygiene and storage facilities. Multivitamins and mineral preparations are widely used for infants and children.

These preparations contain a variety of excipients (“inert ingredients”). Excipients are generally safe; however, adverse effects have been attributed to them. Complete information about the excipients in various preparations is not readily available. The mandatory listing of all excipients is the only way to assure that physicians and consumers will be fully informed about the hidden ingredients.

Heavy metals may just be one of the several contaminants in pediatric syrups either produced or imported into Nigeria, several deaths were reported in Nigeria recently as a result of usage of propylene glycol contaminated with diethylene glycol in production of ‘my pikin teething’ paracetamol syrup by a local pharmaceutical company (43). The presence of metals in seven key herbal mixtures is of serious concern, as this drug is in high demand in Nigeria for treating measles.

The Nigerian made syrup samples had higher concentrations of chromium, nickel and manganese. One fact which is evident in this study is that all the pediatric syrups were duly registered by the Food and Drug regulatory agency. It could therefore be inferred that heavy metals are not regulated in medicaments in Nigeria unlike most other countries. Therefore, it is expedient in the interest of public health to introduce mandatory testing for heavy metals for every batch of drug that is produced or imported into the country. Permissible limits for these heavy metals will be as recommended by WHO publication. Conspicuous display on the container or packaging of these medicines should bear the inscriptions like ‘Heavy metals within permissible limits’.

It is feared that ingestion of these syrups may constitute a significant route of heavy metal exposure to the children and should therefore be considered a public health problem especially with over dosages arising from self prescription by care givers and parents. The public health hazards from ingestion of these syrups should be identified and disclosed by in-Department risk assessment studies.

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# EFFECTS OF CAMEROONIAN FOLK NATURAL SUBSTANCES, NUTRACEUTICALS AND FOODS ON PRE-, PERI- AND POST- GESTATION

Asongalem Emmanuel Acha, Assob Jules Clement Nguedia  
Faculty of Health Sciences, University of Buea, Cameroon

## Background

Africa is overloaded with semi-synthetic and synthetic xenobiotics (e.g. pesticides, food additives, components of packaging, industrial wastes, and noxious gases) and chemical substances existing also naturally (e.g. heavy metals). These substances, present via the environment and the food chains in edible plants and food producing animals may act as endocrine disrupters, with implications on sterility and infertility.

On the other side, childlessness in Africa exposes couples to mixture of derision and sympathy. To circumvent sterility and infertility, couples usually consult traditional medical practitioners who use decoctions and concoctions of plants to perform the treatment. These plants need to be tested experimentally to ascertain their efficacy and potency.

The Toxicology Unit of the Department of Biomedical Sciences at the University of Buea is at the forefront of investigating the reproductive and developmental toxicity of these plants in Cameroon (1, 2) and present here a review of the most used plants.

## Plants used in reproductive related illnesses

These are natural plants used in Cameroon to treat various reproductive related diseases or ailments. They are selected from articles and books published on Cameroonian ethnopharmacology (3-7). Most are used pre-gestationally especially for women looking for the fruit of the womb. The plants are discussed based on sex, the gestational period and diseases as well as scientific evidence justifying their uses.

## Pharmacological and toxicological studies on plants used pre-gestationally

### Urinary tract infections

Plants used against urinary tract infections in Cameroon are reported in Table 1. *Acanthus montanus* possesses antiinflammatory properties (8, 9), moderate antimicrobial effects on *Pseudomonas aeruginosa* and *Staphylococcus aureus* and anti immunological effects (9). *Acacia nilotica* have shown antibacterial (10), antifungal (11), antihepatotoxic and antinephrotoxic-Cadmium induced effects (12), antihypertensive and antispasmodic (13) and anti-inflammatory properties (14). No pharmacological work has been done on *Asystasia macrophylla* but a similar species, *Asystasia gangeticum* has shown Gram + and - antibacterial properties (15) and anti asthmatic effects (16).



Table 1. Plants used against urinary tract infections in Cameroon

Scientific name	Family	Plant fraction	Disease	Preparation	Dosage	Location
<i>Acacia nilotica</i> (gum Arabic)	Mimosaceae	Roots	Gonorrhoea	Decoction	Drink, 3x/d/7 days	North
<i>Acanthus montanus</i>	Acanthaceae	Leaves	Gonorrhoea	Concoction ( <i>Cissus quadrangularis</i> )	3x/d/3 days	South West
<i>Asystasia macrophylla</i>	Acanthaceae	Roots/ stems	Urinary tract infection, wound	Decoction	Chew, 1x/d/30 days	South West
<i>Baseila alba</i>	Baseillaceae	Leaves	Gonorrhoea	Decoction	3x/d/30 days	West
<i>Bosweillia dalzielii</i>	Burseraceae	Roots	Syphilis	Decoction	1x/d/30 days	Adamawa
<i>Burkea africana</i>	Caesalpiaceae	Roots	Gonorrhoea	Chew	1x/d/30 days	Far North
<i>Ceiba pentandra</i>	Bombacaceae	Leaves, stem, roots	AIDS	Decoction	3x/d/30 days	Centre, South West
<i>Ipomoea mauritiana</i>	Convolvulaceae	Back	Syphilis	Decoction	Enema, 1x/3days  Drink, 2x/d/6days	Centre
<i>Markhamia lutea</i>	Bignoniaceae	Leaves, roots	Syphilis	Decoction	2x/d/7 days	North West
<i>Pittosporum viridiflorum</i>	Pittosporaceae	Bark	Syphilis	Concoction ( <i>Aguaria salicifolia</i> )	1x/d/4 days	North West

In Cameroon, *Bacella alba* have been shown not to possess antimicrobial properties but to stimulate both testosterone and estrogen production (17). Bosweillic acids obtained from *Bosweillia* spp. are responsible in some natural herbal products against rheumatism. *Bosweillia dalzielii* has shown no antimicrobial activities (18), but others namely *B. serrata* had high activities against *Candida* spp. responsible for thrush (19) antifungal and antibacterial effects (20). *Ceiba pentandra* possesses antiinflammatory properties (21) and antihepatotoxic effect (22).

No reproductive or developmental toxicity has been conducted on *Acacia nilotica* but its toxicity on rats showed low toxicity at 2-8% with no changes on liver and kidney function biomarkers (14). Apart from *Acanthus montanus*, none of these plants has been tested for its reproductive and developmental toxicity. The aqueous extract of *Acanthus* was found to inhibit fertility and pre-implantation due to oestral cycle disruption; it is also teratogenic and inhibits growth and developmental (1) but its organic extract had no such effects (23). These findings reveal that its pre-gestational use can lead to infertility.

## Sexually transmitted diseases

Plants used in the treatment of sexually transmitted diseases in Cameroon are reported in Table 2. *Ceiba pentandra* has substantial amount of phenolics compound, alkanoid, flavonoid, tannin, sponnin, phytate, oxalate, trypsin inhibitor and hemagglutinin (24).

**Table 2. Plants used in the treatment of sexually transmitted diseases in Cameroon**

Scientific name	Family	Plant fraction	Disease	Preparation	Dosage	Location
<i>Ceiba pentandra</i>	Bombacaceae	Leaves, stem, roots	AIDS	Decoction	3x/d/30days	Centre, South West
<i>Chrysanthelium indicum</i>	Asteraceae	Whole plant	Hepatitis	Decoction	2x/d/30days	West
<i>Ficus thonningit</i>	Moraceae	Bark	Hepatitis	Concoction ( <i>Hallea stipulosa</i> )	3x/d/30days	West

These bioactive compounds (flavonoid, alkaloids, phenolics and saponnins) are known to exhibit physiological and pharmacological activities (25). Flavonoids have been shown to have anti-mutagenic, antibacterial, anti-inflammatory, antiallergic, antiviral, anti-neoplastic, anti-thrombotic and vasodilatory activity (26). The effects of the aqueous extract of *Chrysanthelium indicum* on calcium activation and mobilization have been proven (27). *Ficus thonningii* is known for its anti-inflammatory properties and other family members like *Ficus polita* have been shown to possess antimicrobial properties (28). Its short term toxicity study suggests that oral administration may not exert severe toxic effects in rats at doses lower than 500 mg/kg (29).

## Dysmenorrhoea

Plants used in the treatment of dysmenorrhoea in Cameroon are reported in Table 3.

**Table 3. Plants used in the treatment of dysmenorrhoea in Cameroon**

Scientific name	Family	Plant fraction	Disease	Preparation	Dosage	Location
<i>Acanthus montanus</i>	<i>Acanthaceae</i>	Leaves	Dysmenorrhoea	Concoction ( <i>Cissus quadrangularis</i> )	3x/d/3days	South West
<i>Aloe vera</i>	<i>Liliaceae</i>	Leaves	Dysmenorrhoea	Concoction ( <i>Aloe buettneri</i> , melon seeds)	3x/d/2days	West
<i>Ampelocissus africana</i>	<i>Vitaceae</i>	Roots	Dysmenorrhoea	Decoction	2/day/5days	North
<i>Gardenia aqualla</i>	<i>Rubiaceae</i>	Roots	Dysmenorrhoea	Decoction	2xd/7days	North
<i>Harungana madagascariensis</i>	<i>Hypericaceae</i>	Leaves, bark	Dysmenorrhoea	Decoction	3x/d/5days	Littoral
<i>Jatroerhiza macrantha</i>	<i>Euphorbiaceae</i>	Stem, sap	Dysmenorrhoea	Decoction	1/day/4days	South West
<i>Tamarindus indica</i>	<i>Caesalpiaceae</i>	Leaves, fruits	Dysmenorrhoea	Decoction	3x/d/7days	North

No work has been performed on *Ampelocissus africana* and *Gardenia aqualla*. *Harungana madagascariensis* hydrolysed extract has been shown to possess antioxidant properties (30) which could contribute in scavenging the radicals involved in microsomal lipid peroxidation or protein oxidation responsible for hepatitis; it has antibacterial activity with the possibility of being used to treat opportunistic infections resulting from HIV/AIDS (31) and antimalaria treatments (32). *Jatroerhiza macrantha* has not yet been tested to confirm its smooth relaxant or prostaglandins synthesis inhibitory properties. The ethnomedical use of this plant to treat dymenorrhoea has no scientific basis. The fruits of *Tamarindus indica* has been shown to exhibit spasmolytic effects on rabbit jejunum (33), leaves had antimicrobial activities (34).

There are no toxicological studies done to ascertain the adverse effects of these plants on pregnant and non-pregnant animals. Aqueous–methanolic extract of *Tamarindus indica* and 3 other plants protected the oxidative testicular damage resulting from induced diabetes due to the antioxidant activity of the extract (34).

### Menstruation disorders

Plants used against menstruation disorders in Cameroon are reported in Table 4. *Acanthospermum hispidum* and *Alchornea cordifolia* are plants found to have antimalaria properties (31). *In vitro* studies also demonstrated its anticancer effects with IC50 less than 50 µg/mL (35). *Hibiscus sabdariffa* is a popular drink sold in Cameroon (as folere). It has endothelial dependent vasorelaxant effects (36). *Kaya senegalensis* root bark methanolic extract was found to be ineffective in treating abortion due to poor contraction of the rat uterine smooth muscle (37) had dual agonist activity on rat bladder smooth muscle (38) and its use during menstruation is due to its analgesic properties (39). *Asystasia gangatica* possesses antioxidant and antidiabetic potential (40). None of the plants has been scientifically tested to carry out any of the purported uses during menstruation.

**Table 4. Plants used against menstruation disorders in Cameroon**

Scientific name	Family	Plant fraction	Disease	Preparation	Dosage	Location
<i>Acanthospermum hispidum</i>	<i>Asteraceae</i>	Leaves	Amenorrhoea	Decoction; enema	2x/d/30days	Adamawa
<i>Alchornea cordifolia</i>	<i>Euphorbiaceae</i>	Leaves	Leucorrhoea	paste	Vaginal, 12h	Centre
<i>Asystasia gangatica</i>	<i>Acanthaceae</i>	Aerial parts	Oligo-menorrhoea	Infusion	Drink 2x/d/7days Enema 2x/d/2days	South West
<i>Harungana madagascariensis</i>	<i>Hypericaceae</i>	Leaves, bark	Irregular menses	Decoction	3x/d/5days	Littoral
<i>Hibiscus sabdariffa</i>	<i>Malvaceae</i>	Leafy twigs	Leucorrhoea	Decoction	Vaginal, 1x/d/10days	Centre
<i>Kaya senegalensis</i>	<i>Meliaceae</i>	Bark	Irregular menses	Decoction	2x/d/3days	East
<i>Ocimum basilicum</i>	<i>Lamiaceae</i>	Leaves, flower	Delayed menses	Decoction	2x/d/4days	West

*Hibiscus sabdariffa* has been widely studied and found to increase Alanine aminotransferase (ALT) and creatinine levels with no histopathological effects (41). It is thought to provide

blood. It was found to be toxic to rats after 7-days treatment (41). *Kaya senegalensis* ethanolic extract had deleterious effects on the kidney of rats when given for a prolonged period of 18 days (42), and reduce glutathione liver content (43).

### Infertility and sterility

Plants used in the treatment of infertility and sterility in Cameroon are reported in Table 5. *Albizia adianthifolia* has the potential as an anti-Candida (44), anti-inflammatory and analgesic properties due the presence of saponins (45) had cytotoxic effects on human leukemia T-cells and splenocytes (45) *Allium cepa* (onion) demonstrated antispasmodic properties on rat ileum (46) hypoglycemic and antioxidant effects (47).

*Albizia lebeck* bark showed a general reduction in testes weight, spermatogenic cells, and seminal fluid content such as fructose, cholesterol and protein as well as antiandrogenic effects (48) They did not show no hematological and nor biochemical changes in blood. This finding debunks the use of the plant to treat fertility or sterility rather its use promotes the illness. Freshly prepared *Allium cepa* or onion juice significantly enhanced the sperm count, percentage of viability, and motility of sperms in rats (49) although it has been shown to possess antifertility effects due to its antiimplantation activity (50).

**Table 5. Plants used in the treatment of infertility and sterility in Cameroon**

Scientific name	Family	Plant fraction	Disease	Preparation	Dosage schedule	Location
<i>Albizia adianthifolia</i>	Caesalpinaceae	Leaves, bark, roots	Sterility	Decoction; enema	3x/d/30days	Littoral
<i>Allium cepa</i> (onion)	Liliaceae	Rhizome	Sexual weakness	Decoction	Drink 3x/d/7days	All
<i>Burkea africana</i>	Caesalpinaceae	Roots	Impotence	chew	1x/d/30days	North
<i>Combretum</i> spp.	Combretaceae	Bark, roots	Impotence	Decoction	1x/d/30days	South West
<i>Crossopteryx febrifuga</i>	Rubiaceae	Fruits, bark	Sterility	Maceration	3x/d/30days	Far North
<i>Cyperus</i> spp.	Cyperaceae	Whole plant, roots	Sterility	Decoction, cooking	1x/d/30days	South West
<i>Entada africana</i>	Mimosaceae	Bark	Impotence	Decoction	2/d/30days	Adamawa
<i>Euphorbia hirta</i>	Euphorbiaceae	Bark	impotence	Decoction	1x/d/30days	Littoral
<i>Impatiens</i> spp.	Basalminaceae	Leaves, Stem	Infertility	Decoction	2x/d/30days	South West
<i>Leucaena leucocephala</i>	Caesalpinaceae	Leaves, fruits	Eases conception	Decoction	1x/d/20days	South West
<i>Ricinus communis</i>	Euphorbiaceae	Leaves, stem, roots	Sterility	Decoction	2x/d/30days	South West
<i>Tapinanthus</i> spp.	Loranthaceae	Whole plant	Sterility	Maceration	1x/d/30days	South West
<i>Terminalia superba</i>	Combretaceae	Stem	Infertility	Decoction	2x/d/7days	Adamawa

## Ovarian cyst or fibroid

Plants used against ovarian cyst or fibroid in Cameroon are reported in Table 6. *Acacia nilotica* possess antihypertensive antispasmodic properties (13); antibacterial activities against diarrhoeal causing bacteria species (51). *Acacia nilotica ssp adansonii* can stimulate milk production in lactating women (52). It has an anti-inflammatory active androstene steroid. It also has D-pinitol, kaempferol, gallic acid, ellagic acid, epicatechin, and rutin. *Acacia nilotica*, at 2% and 8% levels, has a low toxicity potential (14). Hence, the utility of *A. nilotica* bark can cleanup of toxic elements in aqueous solutions through removal of toxic metals (52). *Ekebergia senegalensis* has been shown to possess antimicrobial and antioxidant properties (53); antimalarial (54). The aqueous ethanolic extract of *Hymenocardia acida* stem bark could induce negative effects on reproductive functions in female albino rats (55). Amongst the various pharmacological properties of *Vernonia* spp, its uterine smooth muscle relaxant properties are due to its content in glaucolide E (47).

*Ximenia Americana* is used in Northern Peru for menstrual regulation (56). However none of these plants in table 6 have been evaluated for their pharmacological activities against ovarian cyst or fibroid.

**Table 6. Plants used against ovarian cyst or fibroid in Cameroon.**

Scientific name	Family	Plant fraction	Disease	Preparation	Dosage schedule	Location
<i>Acacia nilotica</i>	<i>Mimosaceae</i>	Roots	fibroid	Decoction	Drink, 3x/d/7days	North
<i>Ekebergia senegalensis</i>	<i>Maliaceae</i>	Bark	Ovarian cyst	Maceration	1x/d/10days	Far North
<i>Laportea camara</i>	<i>Urticaceae</i>	Leaves, stem, roots	Fibroid	Decoction, cooking	3x/d/10days	South West
<i>Hymenocardia acida</i>	<i>Euphorbiaceae</i>	Leaves	Fibroid	Decoction	Drink 3x/d/7days	North, South West
<i>Securidaceae longepedunculata</i>	<i>Polygalaceae</i>	Leaves, Roots	Ovarian cyst	Decoction	3x/d/30days	Adamawa
<i>Senna sanqueana</i>	<i>Caesalpinaceae</i>	Bark	Fibroid	Maceration	1x/d/30days	Far North
<i>Vernonia</i> spp.	<i>Asteraceae</i>	Roots	Ovarian cyst	Infusion	1/d/30days	Adamawa
<i>Ximenia americana</i>	<i>Olacaceae</i>	Roots	Fibroid	Infusion	3x/d/30days	Adamawa

## Pharmacological and toxicological studies on plants used peri-gestationally

### Threatened abortion

Plants used against threatened abortion in Cameroon are reported in Table 7. *Acanthus montanus* possesses several medicinal properties; it is used in Cameroon as a folk medicine to treat pain, inflammation and threatened abortion (1). The aqueous was proven not to alter the uterine wet weight or deciduoma count, suggesting a lack of estrogenic and progestational effects. At 1000 mg/kg/day, the extract caused appreciable preimplantation losses of  $36.8 \pm 6.5\%$  ( $P < 0.05$ ), while none of the doses caused postimplantation losses (1).

Table 7. Plants used against threatened abortion in Cameroon

Scientific name	Family	Plant fraction	Disease	Preparation	Dosage schedule	Location
<i>Acanthus montanus</i>	Acanthaceae	Leaves	Threatened abortion	Decoction	3x/d/10days	South West
<i>Bidens pilosa</i>	Asteraceae	Leaves	Threatened abortion	Decoction	3x/d/3days	Littoral
<i>Crossopteryx febrifuga</i>	Rubiaceae	Fruits, bark	Threatened abortion	Maceration	3x/d/30days	Far North
<i>Hibiscus sabdariffa</i>	Malvaceae	Leaves, stem	Threatened abortion	Maceration	3x/d/3days	South West
<i>Hymenocardia acida</i>	Euphorbiaceae	Leaves	Threatened abortion	Decoction	Drink 3x/d/10days	North, South West
<i>Hymenocardia acida</i>	Euphorbiaceae	Leaves	Fibroid	Decoction	Drink 3x/d/7days	North, South West
<i>Mormodica foetida</i>	Cucurbitaceae	Leaves	Threatened abortion	Decoction	2xd/10days	South West
<i>Piper guinensis</i>	Piperaceae	Fruits	Threatened abortion	Concoction ( <i>Borreria ocymoides</i> )	2x/d/days	All
<i>Senna sanguinea</i>	Caesalpinaceae	Bark	Threatened abortion	Maceration	1x/d/30days	Far North
<i>Vernonia stelligera</i>	Asteraceae	Whole plant	Stops miscarriage	Decoction	2x/d/30days	South West
<i>Voanzou subterana</i>	Fabaceae	Whole plant	Threatened abortion	Concoction ( <i>Sida acuata</i> )	1x/d/30days	Far North

*Bidens pilosa* have been shown to possess hypotensive effect with action on smooth muscle relaxant properties and a vasodilatory action possibly caused by calcium antagonist action and beta-receptor stimulation (57,58,59). Information regarding safety and efficacy during pregnancy and lactation is lacking. *B. pilosa* had shown antimicrobial properties against *Bacillus coagulans*, *Citrobacter freundii*, and *Salmonella typhi* (60, 61) but not on *Candida albicans* (62). A minimum inhibitory concentration of 50 mcg/mL was obtained from a sesquiterpene phenol from *B. cernua* for *Candida* (62, 63). *Hibiscus sabdariffa* is used in Uganda for anemia (64). All these medicinal plants lack scientific data on their efficacy in the treatment of fibroids, threatened abortion.

### Foetal malpositioning

Plants used to resolve foetal malpositioning in Cameroon are reported in Table 8. *Senecio biafrae* (*Asteraceae*) is a medicinal plant widely used by traditional healers in the western region of Cameroon for the treatment of female infertility (65).

A study of the aqueous extract from leaves and stems of *S. biafrae* (AESb) on the onset of puberty and some biochemical and physiological parameters of reproduction in immature Wistar female rats showed that it possesses an ovarian folliculogenesis effect and puberty onset induction (66). No data available on their specific pharmacological properties on foetal malpositioning.

**Table 8. Plants used to resolve foetal malpositioning in Cameroon.**

Scientific name	Family	Plant fraction	Disease	Preparation	Dosage schedule	Location
<i>Piper umbellatum</i>	Piperaceae	Leaves	Foetal malpositioning	Decoction	Once daily	All
<i>Senecio biafrae</i>	Asteraceae	Leafy twigs	Foetal malpositioning	Decoction	2x/d/5days	South West

### Intrauterine death

Plants used to resolve intrauterine death in Cameroon are reported in Table 9. *Abrus precatorius* and *Terminalia glaucescens* have not yet been study for their pharmacological properties.

**Table 9. Plants used to resolve intrauterine death in Cameroon.**

Scientific name	Family	Plant fraction	Disease	Preparation	Dosage schedule	Location
<i>Abrus precatorius</i>	Asteraceae	Leaves	Retained death foetus	Concoction (Aframomium spp.)	Once daily	South West
<i>Terminalia glaucescens</i>	Combretaceae	Bark	Retained death foetus	Decoction	Once daily/enema/3days	South, South West

### Delivery

Plants used for facilitated delivery in Cameroon are reported in Table 10. *Cassia alata* has been known to provide relief from various types of abnormal skin conditions (67). Leaf decoction of *C. alata* is taken three times a day for 2 days to kill foetus in uterus. Some women who have used the plants remain sterile (68). *Commelina bengalensis*, *Gnetum africanum*, *Plectranthus ducurrens* and *Solenostemon monostachyus* are used in the South West region of Cameroon to ease child birth (4). Pharmacological studies showing their ability to ease child delivery are still yet to be determined.

**Table 10. Plants used for facilitated delivery in Cameroon**

Scientific name	Family	Plant fraction	Disease	Preparation	Dosage schedule	Location
<i>Cassia alata</i>	Caesalpinaceae	Leaves, roots	Fastens delivery	Decoction	3x/d/2days	South West
<i>Commelina benghalensis</i>	Commelinaceae	Whole plant	Eases child delivery	Decoction	2x/d/2days	South West
<i>Gnetum africanum</i>	Gnetaceae	Leaves	Eases child birth	Decoction	2x/d/3days	Centre, South West
<i>Plectranthus ducurrens</i>	Lamiaceae	Whole plant	Eases child delivery	Decoction	2x/d/2days	South West
<i>Solenostemon monostachyus</i>	Lamiaceae	Leafy stem	Eases child delivery	Decoction	2x/d/2day	South West

## Pharmacological and toxicological studies on plants used post-gestationally

### Placental retention

Plants used against placental retention in Cameroon are reported in Table 11. No studies have been done on the potential placental retention properties of *Bidens pilosa* and *Tetrapleura tetraptera*.

**Table 11. Plants used against placental retention in Cameroon**

Scientific name	Family	Plant fraction	Disease	Preparation	Dosage schedule	Location
<i>Bidens pilosa</i>	Asteraceae	Leaves	Placental retention	Decoction	3x/d/3days	Littoral
<i>Tetrapleura tetraptera</i>	Leguminosae-Mimosoideae	Roots	Placental retention	Decoction Powder	Enema 2x/d 1tsp/3x/d	West

### Post partum hemorrhage

Plants used against post partum hemorrhage in Cameroon are reported in Table 12.

**Table 12. Plants used against post partum hemorrhage in Cameroon**

Scientific name	Family	Plant fraction	Disease	Preparation	Dosage schedule	Location
<i>Cogniauxia podolaena</i>	Cucurbitaceae	Tubers	Haemorrhage	Pounded	Tie around waist/3days	Centre
<i>Tetrapleura tetraptera</i>	Leguminosae-Mimosoideae	Fruit	Placental retention	Decoction	Enema 3x/d/10	West
<i>Heisteria zimmereri</i>	Olacaceae	Bark	Haemorrhage	Decoction	3x/d/5days	Centre

*Cogniauxia podolaena* Baill. (Cucurbitaceae) is traditionally used in Congo Brazzaville malaria treatment. Its extract and products (three triterpenes, cucurbitacin B, cucurbitacin D and 20-epibryonolic acid) are good antiplasmodial agents. Cucurbitacin B, cucurbitacin D showed high cytotoxicity whereas 20-epibryonolic acid showed a better selectivity index (69). It also possesses good analgesic properties (70). No pharmacological study available on *Heisteria zimmereri* and its anti hemorrhage properties.

### Lactation failure

Plants used against lactation failure in Cameroon are reported in Table 13. The mammary glands of oestrogen-primed rats treated with the *Acacia nilotica* aqueous extract showed clear lobuloalveolar development with milk secretion. This study demonstrates that the aqueous extract of *Acacia nilotica* can stimulate milk production and prolactin release in the female rat and could consequently have the properties claimed for lactating women (71). *Alstonia boonei*, *Commelina benghaliensis*, *Crinum zeylanicum*, *Garcinia kola* and *Guiera senegalensis* lactogenic properties are still yet to be determined.



Table 13. Plants used against lactation failure in Cameroon

Scientific name	Family	Plant fraction	Disease	Preparation	Dosage schedule	Location
<i>Acacia nilotica</i>	Fabaceae	Fresh leaves	Lactation failure	Decoction	100 g dry leaves per day	South West
<i>Alstonia boonei</i>	Apocynaceae	Bark, latex, leaves	Lactation failure	Decoction	3x/d/3days	South West
<i>Commelina benghalensis</i>	Commelinaceae	Whole plant	Lactation failure	Decoction	2x/d/2days	South West
<i>Crinum zeylanicum</i>	Amaryllidaceae	Bulb	Lactation failure	Powder/with Sorghum	2 tsp, 3x/d/3days	West
<i>Garcinia kola</i>	Clusiaceae	Bark, seeds, roots	Speeds lactation	Decoction	3x/d/2days	Littoral, South West
<i>Guiera senegalensis</i>	Combretaceae	Leaves	Lactation failure	Decoction	2x/d/2 wks	Centre

## Conclusion

This review of Cameroonian medicinal plants on the effects of folk natural substances, nutraceuticals and foods on pre-, peri- and post- gestation is intended to serve as the scientific baseline information for the use of the documented plants, as well as a starting point for future studies, leading to the production of improved phytomedicines against reproductive illnesses. This study revealed the richness of Cameroon in terms of biodiversity with approximately fifty medicinal identified. Eleven plants are used against urinary tract infections, best been, *Acacia nilotica*; three plants are used against sexually transmissible diseases; seven plants are identified in the treatment of amenorrhoea and menstrual disturbances, with *Khaya senegalensis* confirmed analgesic properties. Thirteen medicinal plants are identified in the treatment of sterility and infertility. *Allium cepa* or onion juice significantly enhanced the sperm count, percentage of viability, and motility of sperms in rats. Eight medicinal plants are used against fibroids and ovarian cysts, and *Vernonia* spp. have been shown to possess uterine smooth muscle relaxant properties; twelve medicinal plants are used to resolve threatened abortion; two plants are used against fetal mal-positioning, two against retained death fetus; five plants are used to ease delivery; three to resolve placental retention; whereas three are lactogenic.

Although some of traditional uses of these medicinal plants were confirmed scientifically, some other with established pharmacological studies showed properties opposite to their traditional use, whereas some had no medicinal values.

The need for the rational study of these medicinal plants is urgent in order to prove their pharmacological properties, to establish their therapeutic doses in order to produce safe phytomedications at low cost.

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## DUMPING OF BANNED BABY BOTTLES FROM ADVANCED ECONOMIES: AN OVERLOOKED HAZARD FOR AFRICAN INFANTS?

Guy Bertrand Pouokam (a), Godwin Chukwuebuka Ajaezi (b), Chiara Frazzoli (c), Orish Ebere Orisakwe (d), Alberto Mantovani (c)

(a) Faculty of Science, University of Yaoundé I, Cameroon

(b) Rivers State University of Science and Technology, Nigeria

(c) Department of Veterinary Public Health and Food Safety, Istituto Superiore di Sanità, Italy

(d) Faculty of Pharmacy, University of Port Harcourt, Nigeria

### Introduction

Bisphenol A, 2,2-bis(4-hydroxyphenyl)propane, CAS Number 80-05-7 (Figure 1), commonly abbreviated as BPA is the monomer of polycarbonate plastic and epoxy resins widely used in food contact materials such as infant feeding bottles, containers of solid and liquid foods and water pipes. Epoxy resins are used as protective lining for variety of canned foods and beverages and as a coating on metal lids for bottles, including containers used for infant formulae.

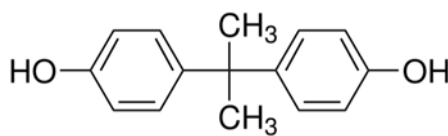


Figure 1. BPA Structure (IUPAC name: 4,4'-dihydroxy-2,2-diphenylpropane)

Notwithstanding its usefulness in a number of consumer's products, BPA is also an issue of intense scientific and regulatory interest because of its endocrine activity. The last decade has experienced an increase in BPA toxicity and epidemiological studies, to identify and characterize potential effects at very low exposure levels on the development of reproductive, neuro-developmental, and cognitive systems (1).

Meetings and workshops have been organized at international level to review the existing scientific literature, clarify the areas of uncertainties and provide advice on the human's adverse health effects and their dose-response relationship. Recently the World Health Organization (1) and the European Food Safety Authority (EFSA) (2) has published documents on BPA; noticeably, the EFSA has started a re-evaluation of BPA focusing on potential low-dose effects, as well as on aggregate exposure from food and non-food sources (3). The areas of uncertainties over the safety of a material commonly used in baby bottles have led decision makers to apply precautionary measures, banning the use of BPA material in the manufacturing of babies feeding equipment outside Europe, in Minnesota and Massachusetts states in the USA (2009), Canada (2010), Japan (2010), China (2011) (4). In 2011, the European Union has also banned the commercialisation and manufacture of BPA baby bottles (5). No African countries have raised concern on this matter till now. Indeed, most African countries do not manufacture baby bottles, but they do import from more industrialized economies. With the on-going restrictions

and bans in other world's areas, there is a threat of massive dumping of BPA-containing polycarbonate bottles in the African markets.

## Health hazards associated with BPA exposure

In 2006 (opinion published in 2007), the EFSA set a Tolerable Daily Intake (TDI) for BP of 0.05 mg BPA/kg body weight/day. The TDI was based on a NOAEL (No Observed Adverse Effect Level) of 5 mg/kg<sub>bw</sub>/day, identified in two multi-generation reproductive toxicity studies in rodents, where the critical effects were reduced body weight gain and changes in organ weights (adults and offspring) and liver effects (adults) in rats and mice, respectively (6). TDI is set to protect for lifetime exposure, while considering also potentially more sensitive population groups, e.g., pregnant women and small children. However, several scientific groups have questioned the EFSA TDI, since BPA is an Endocrine Disrupting Chemical (EDC), acting via diverse mechanism. BPA binds both estrogen nuclear receptors  $\alpha$  and  $\beta$  (ER $\alpha$  and ER $\beta$ ), with approximately 10-folds higher affinity to ER $\beta$ . The affinity of BPA for ERs is 10.000–100.000 folds weaker than that of estradiol (7); thus, based on receptor binding, rather high BPA intake levels might be required to elicit estrogen-like effects. However, recent studies on molecular mechanisms revealed a variety of pathways through which BPA can stimulate hormone-related cellular responses at low concentrations *in vitro*, including interactions with androgens or thyroid hormones and with the redox homeostasis, inhibition of cell cycle and cell differentiation, modulation of the activity or expression of steroidogenic enzymes (1, 2). The comprehensive assessment of available epidemiological and toxicological studies carried out in 2010 by the EFSA Panel on Food Contact Materials, Enzymes, Flavourings and Processing Aids delivered a majority opinion stating that no new study could be identified, which would call for a revision of the TDI, and that the TDI can be considered conservative as humans seem to metabolize BPA more efficiently than rodents. The Panel also acknowledged that recent epidemiological studies have suggested statistically significant associations of BPA exposure and adverse health effects in humans (coronary heart disease, reproductive disorders and behavioural changes in young girls); however, limitations in study design prevented the use of such studies for risk assessment. In addition, some studies conducted on developing animals suggested BPA-related adverse effects (biochemical changes in brain, immune modulation) and enhanced susceptibility to breast tumours) at dose levels much lower than the NOAEL used to establish the TDI: these studies had several shortcomings, and the relevance of their findings for human health could not be assessed. Finally, the Panel stated its availability to reconsider the opinion, should more relevant data become available. One member of the Panel expressed a minority opinion, that the full weight of evidence threw serious uncertainties on the validity of the current TDI to protect the developing organism (foetus and small child) and indicated that BPA intake by infants should be reduced; in particular, avoiding bottles made out of polycarbonate for formula-fed infants could significantly decrease their potential exposure. The EFSA assessment, as well as the resuming of BPA evaluation this year (3), clearly shows the many remaining doubts (and potential concerns) about the safety of this plastic additive, and indicates the ground for precautionary bans and limitations issued by several industrialized countries (4, 5).

## Human exposure

Although exposure to BPA can occur via dermal and oral routes, most studies till have focused on dietary sources, due to widespread use of BPA-containing, polycarbonate-based

food contact materials. Polycarbonate feeding bottles are, by far, the main source of exposure to BPA for infants (6).

The release of BPA into aqueous liquids is directly related to contact time, temperature and pH of the food matrix; on the contrary, brushing of the bottle does not seem to increase the release of BPA. Some food preparation processes increasing the food pH do also enhance the release of BPA (6).

The highest dietary intake is estimated to occur in the period when infant consumes exclusively liquid food (from birth to 3-6 months). In 2002, the range of migration from polycarbonate feeding bottles into water and infant formulae was considered to be <10 to 20 µg BPA/kg food by a former European body, the Scientific Committee on Food (SCF). Higher migration values obtained under aggressive conditions were not considered as representations of the existing uses; this might be somewhat debatable, since the up-to-date science of risk assessment considers also reasonable worst cases. Considering an intake of 0.7 L formula per day in infants aged 0-4 months and weighing 4.5 kg, a migration level of 10 µg BPA/kg of infant formula would have led to a potential exposure of 1.6 µg/kg<sub>bw</sub>/day, i.e., about 3% of the current EFSA TDI (6). Whilst acknowledging the previous work carried out by SCF, the EFSA in its 2006 opinion intended to produce a more refined and in-depth exposure assessment. Table 1, adapted from (6), provides conservative estimates the dietary exposure to BPA in infants and small children, as the only age groups where intake might get near to the TDI.

From 15 to 24 months, consumptions patterns keep changing from infants' formulae feeding and baby food to a mix scenario that is increasingly similar, though not identical, to adult diet. Thus, the infant below 1 year is the most exposed. The EFSA estimate is much more conservative than that of SCF, but the top estimate of infant exposure never gets up to 30% of the current TDI of 50 µg/kg<sub>bw</sub>/day.

The conclusion of the joint FAO/WHO expert meeting to review BPA health effects indicate a trivial exposure of exclusively breastfed babies (0-6 months), i.e., 0.3 and 1.3 µg/kg<sub>bw</sub> per day (mean and 95<sup>th</sup> percentile). Exposure estimates are generally higher for infants fed with liquid compared with powdered formula and for infants fed using polycarbonate compared with non-polycarbonate bottles. The highest estimated exposure occurs in infants 0-6 months of age who are fed with liquid formula out of polycarbonate bottles: 2.4 and 4.5 µg/kg<sub>bw</sub> per day (mean and 95<sup>th</sup> percentile). Once solid foods are introduced (at 6-36 months), exposure to BPA decreases: intake of children above 3 years would be 0.7 and 1.9 µg/kg<sub>bw</sub> per day (mean and 95<sup>th</sup> percentile). For adults, including pregnant women, exposure estimates (mean and 95<sup>th</sup> percentile) are 1.4 and 4.2 µg/kg<sub>bw</sub> per day (1). Therefore, the FAO/WHO estimate is less conservative than EFSA, since the highest estimates get slightly below 10% of the TDI. Of course, the messages by EFSA and FAO/WHO would be somewhat less reassuring, when one takes into account the "grey areas" outlined by EFSA in 2010 (2) and the ongoing international debate on the validity of TDI.

Social and economic inequalities are relevant to toxicological risk assessment. A recent study suggests that disadvantaged communities, as represented by the poorer population groups and/or by minorities, are more likely to live in the more hazardous environment as well as to rely on cheap and canned foods; thus, such groups have also a higher chance of exposure to food-related pollutants, such as BPA.

This marked racial segregation, as well as health behaviour's associated with poverty result in differences in exposure to particular EDC, thus leading into significant, persistent and costly racial disparities in pregnancy outcomes between African-Americans and white Americans. The authors propose that disproportionate exposure of African-American women to environmental EDCs could contribute to these birth outcome disparities (8).

In African countries no data are yet available on infants or adult exposure to BPA, although consumption patterns and risks scenarios are numerous and look aggressive.



Table 1. Conservative estimates of potential dietary exposure to BPA

Source of exposure	BPA concentration in food/ beverage ( $\mu\text{g}/\text{kg}$ or $\mu\text{g}/\text{L}$ )	Potential dietary exposure to BPA ( $\mu\text{g}/\text{kg}_{\text{bw}}/\text{day}$ )				
		3 month infant <sup>(1)</sup>			6 months infant <sup>(2)</sup>	child (1.5 years) <sup>(3)</sup>
		<i>breastfed</i>	<i>fed with glass or non-polycarbonate bottles</i>	<i>fed with polycarbonate bottles</i>		
Breast milk	<1	<0.2	-	-	-	-
<b>Migration</b>						
polycarbonate bottles $\rightarrow$ milk	50 or 10 <sup>(4)</sup>	-	-	8.7 or 1.7 <sup>(4)</sup>	5.9 or 1.2 <sup>(4)</sup>	-
epoxyresin can $\rightarrow$ powdered formula	100	-	2.3	2.3	1.6	-
epoxyresin can $\rightarrow$ commercial foods and beverages	100 (infant) 10-50 (child)	- -	- -	- -	5.2 -	- 4.4
polycarbonate tableware	5	-	-	-	0.3	0.9
total		0.2	2.3	11 or 4 <sup>(4)</sup>	13 or 8.3 <sup>(4)</sup>	5.3

1 Infant weighing 6.1 kg, consuming 174 mL/kg<sub>bw</sub> of breast milk or of infant formulae reconstituted from 23 g/kg<sub>bw</sub> of powder.

2 Infant weighing 7.8 kg, consuming 52 g/kg<sub>bw</sub> of commercial foods and beverages and 118 mL/kg<sub>bw</sub> of infant formulae reconstituted from 16 g/kg<sub>bw</sub> of powder.

3 Child weighing 11 kg, consuming 2 kg of commercial foods (one third solid foods, two-thirds beverages).

4 Two exposure scenarios were considered for BPA exposure from polycarbonate bottles in infants. A conservative scenario was based on a concentration value of 50  $\mu\text{gBPA}/\text{L}$  of infant formulae to calculate exposure in infants fed every day with polycarbonate bottles leaching BPA at the highest concentration observed in realistic conditions of use. Another scenario based on migration value of 10  $\mu\text{g BPA}/\text{L}$  was considered in order to estimate exposure in a more typical situation.

## NOODLES pilot survey on plastic baby bottles sold in Africa

### Objectives of the survey

The pilot survey was carried out in the frame of activities of the NOODLES network ([www.noodlesonlus.org](http://www.noodlesonlus.org)). The study aimed at investigating the present situation in Cameroon and Nigeria, namely as regards: i) the available types of baby bottles, ii) those most frequently purchased, iii) the most used sterilizing methods, iv) infant's feeding habits, v) the state of regulations and enforcement measures.

## Methodology

The study was carried out in Nigeria and Cameroon. Two cities in Nigeria: Ikeja (Lagos state), and Port Harcourt (River state) as well as three cities in Cameroon: Yaoundé (Centre region), Bafoussam and Fombot, (West region) were chosen for the survey.

Overall, 34 pharmacies and 87 shops in quarters, especially around hospitals, and open markets were visited, and a total of 172 plastic baby bottles were surveyed (Table 2).

**Table 2. Figures of the pilot survey on plastic baby bottles sold in Cameroon and Nigeria**

Country	Region/state	Town	Number of pharmacy and shops visited	Total number of plastic baby bottles surveyed
Cameroon	Center region	Yaoundé	18 pharmacies + 6 shops	30
	West region	Bafoussam	12 pharmacies + 6 shops	30
	West region	Fombot	2 pharmacies + 6 shops	14
Nigeria	Lagos State	viz Ikeja, Agege, Oshodi and Idumota	2 pharmacies + 36 shops	50
	River State	Port Harcourt	No pharmacies + 33 shops	48

Only bottles displayed in the pharmacy or shop were considered. Questionnaire, face-to-face and group discussion were employed for collecting the following data:

- types of baby bottle sold, their prices, those most purchased
- use of baby bottles: sterilizing methods, and feeding frequency.

Means for bottle prices and feeding frequencies were calculated, while sterilizing and feeding procedures were described.

## Results and discussions

### Type of baby bottles available for the population and the most purchased ones

Findings are reported in figures 2 and 3. Plastic baby bottles not-labelled “BPA free” represented only 2.5% of bottles surveyed in Cameroon’s pharmacies. In Nigeria, baby bottles are not sold in most pharmacies.

On the other hands in Cameroon 100% of plastic bottles surveyed in shops did not carry the label “BPA free” or were not labelled at all. Many labelled bottles had the “No Nitrosamine” message.

In Nigeria shops in Lagos and Port Harcourt showed respectively 80% and 73% of bottles not labelled “BPA free”.

For 240 mL bottles in Cameroon, prices were in average 3500 FCFA in pharmacies and 1500 FCFA in shops. It should be noted that some shop-keepers refused to disclose the prices. Such comparison could not be made in Nigeria, since baby bottles are sold in shops and markets only.

The survey also revealed that most consumers purchase the cheapest bottles as a result of low income. Bottle price is a major consideration as people incomes are low. Moreover, a common opinion believes that items found in pharmacies are more expensive. As a consequence, customers prefer going into shops.

Baby bottles are used in both urban and rural areas, either during mix feeding (formula and breastfeeding up to 6 months) or exclusive formula feeding till 24-36 months.

Nigeria manufactures some of the bottles found locally, whereas those used in Cameroon are all imported, including from Nigeria. However, the majority of the bottles surveyed in Nigeria were imported from Europe and America: 13 out of 48 (27.1%) surveyed in Port Harcourt were locally made.

The pilot survey shows that a substantial BPA exposure of African infants through baby bottles may not be excluded. Such exposure would add-up with mother-child BPA transfer through placenta, colostrum and breast milk (9) as well as with aggregate exposure through diet and consumer products throughout life (10). Nevertheless, scientific evidence point to baby bottles standing as a key exposure source to BPA during a potentially vulnerable life stage (1, 2).

### **Usage patterns and awareness on BPA exposure**

Many women still use boiling to sterilize infant feeding equipment. The woman fills with water a large pan (exclusively for this purpose) with a cover, and submerges all the feeding equipment completely; the pan then is covered and the equipment is made to boil for an undetermined duration. Generally, sterilization is stopped when water is seen to release air bubbles, indicating the boiling point. The pan's cover is kept on until when the equipment is ready to be used.

On average, infant formulae are given till 15 to 24 months of age. An average volume of 210 mL is given before 6 months of age, and up to 240 mL till 24 months of age. Seven tablespoons of milk powder are introduced into 210 mL of cold mineral water. The mixture is then heated into boiled or lukewarm water.

Interviewing with women disclosed that most working mothers use plastic bottles to store breast milk; nannies are compelled to use formula feeding when the breast milk is not available due to the absence of the mothers. Women who do not work increasingly use breastfeeding till 6 months of age. After 6 months, the use of plastic bottles and formulas becomes more and more intensive.

Overall, feeding volume and frequency changes with infant's age and family habits from an exclusive breast feeding to exclusive artificial feeding, drawing therefore different exposure scenario.

Some scenarios (e.g. exclusive long-term formula feeding) look rather aggressive: they should deserve a close look concerning BPA migration, and risk assessment for infants.

Noticeably, our survey disclosed that both pharmacists and shop owners in Nigeria as well as Cameroon towns are unaware of the potential health risks related to BPA exposure.

### **How to identify BPA-free bottles**

None of those interviewed could recognize polycarbonate baby bottles. We therefore reviewed some identification codes and verify their conformity with available bottles. Polycarbonate bottles are generally hard and transparent. They may also be tinted with color. There are seven classes of plastics used in packaging applications. The Society of the Plastics Industry (SPI, <http://www.plasticsindustry.org/>) resin identification coding system is a set of symbols placed on plastics to identify the polymer type. It was developed by the SPI in 1988, and is used internationally. The primary purpose of the codes is to allow efficient separation of different polymer types for recycling.

The symbols used in the code consist of arrows that cycle clockwise to form a rounded triangle and enclosing a number, often with an acronym representing the plastic placed below

the triangle. Contrary to misconceptions, the number does not indicate how hard the item is to recycle, nor how often the plastic was recycled; it is an arbitrarily-assigned number that has no other meaning aside from identifying the specific plastic.

The resin identification codes are included between code points U+2673 and U+2679 inclusive. The generic material recycling symbol is encoded as code point U+267A. When the number is omitted, the symbol is known as the universal recycling symbol, indicating generic recyclable materials. In this case, other text and labels are used to indicate the material(s) used. Previously recycled resins are coded with an “R” prefix (for example, a PETE bottle made of recycled resin could be marked as RPETE using same numbering).

SPI recycling number indicating bottles that can leach BPA are 3 and 7 (Figure 2). Type 7 is the catch-all “other” class, and some Type 7 plastics and epoxy resins are made from BPA monomer. Type 3 (PVC) can also contain Bisphenol A as an antioxidant in plasticizers; this is particularly true for “flexible PVC”, but not true for PVC pipes. Type 6 (polystyrene) neither contains, nor does it break down into Bisphenol A, according to the Styrene Information and Research Center (<http://www.styrene.org/>), whose membership represents approximately 95% of the North American styrene industry.



**Figure 4. SPI recycling numbers indicating bottles that can leach BPA**

*Following the SPI resin identification coding system, the first symbol reports recycling number (U+2675), abbreviation (PVC or V), polymer name (polyvinyl chloride), not to be used for food bottles.*

*The second symbol reports the recycling number (U+2679), abbreviation (OTHER or O), polymer name (other plastics, including acrylic, acrylonitrile butadiene styrene, fiberglass, nylon, polycarbonate, and polylactic acid), not to be used for food bottles.*

## **NOODLES activities for awareness raising**

Given the high availability and accessibility of polycarbonate baby bottles in sub-Saharan African countries, the overall inappropriate and sometimes aggressive conditions of infants’ feeding equipment’s sterilization, infant milk preparation and heating, as well as feeding methods, BPA dietary intake from baby bottles should be looked more closely. Exposure estimates made in industrialized countries revealed an upper range of infant intake always below 15 µg/kg<sub>bw</sub> per day (1, 2). However, such estimates do not account for usage conditions that may occur in developing countries. In sub-Sahara African country scenarios, lack of information and good practices and inappropriate use conditions could make exposure much higher. The possibility of an African dumping of BPA baby bottle banned in industrialized countries should not be overlooked.

During the manifestations organized in Cameroon for the 2010 International Breastfeeding week, NOODLES participate to a group discussion to evaluate the advancement of the exclusive breastfeeding campaigns. The number of women that exclusively breastfeed their child till 6

months is still low (about 23%), meaning that 77% of mothers rely more on baby bottles (glass or plastic) to feed their newborn either through mix or exclusive bottles feeding.

Awareness-raising activities in Cameroon may make avail of Cameroon Radio Television, Centre region station (FM 101.9MHZ): interventions can be one during talk show shows to enlighten consumers (“Service clients”, broadcast each Monday, Wednesday and Friday from 10 to 11 am). The intervention devoted to the “BPA baby bottles” and general relation between food safety and consumers’ health was done on February 18<sup>th</sup> 2011.

NOODLES website and Facebook account aim to encourage group discussions and increase awareness on the implications of BPA exposure for African children ([www.noodlesonlus.org](http://www.noodlesonlus.org)).

In addition, potential health risks from BPA exposure were presented to African scientists during the 3<sup>rd</sup> Congress of the Cameroon Society for Toxicological Sciences and the 5<sup>th</sup> meeting of the Society of Environmental Toxicology and Chemistry (CSTS/SETAC-Africa, May 31<sup>st</sup> - June 3<sup>rd</sup> 2011, Buea, Cameroon).

Information on BPA baby bottles and health risks on babies has also started on paper, with the publication on a Cameroon newspaper (Figure 3).



**Figure 3. A newspaper article of the NOODLES network  
(*The Median*, 10 January 2011, Cameroon)**

NOODLES standpoint is that the general consumer must be informed and, even when the choice has to be cost-driven, appropriate information on how to mitigate the risk from food contact materials should be spread among consumers, for instance (11):

- consider exclusive breastfeeding up to 6 months;
- purchase BPA free plastic bottles;
- replace BPA bottles every 6 months, when affordable;
- avoid filling BPA bottles with boiling liquids but introduce only lukewarm liquid and then feed the infant immediately, thus avoiding prolonged contact of the liquid with the bottle;
- do not use the bottle when you notice the presence of “spider” cracks because at those points there are increase release of BPA;
- do not microwave food in polycarbonate plastic containers, because over time BPA can break down due to high temperatures;
- do not put plastic containers in the dishwasher or use harsh detergents to clean them;
- containers with BPA shouldn’t be hot sterilised because this increases the release of BPA;
- cold sterilization methods should be used and if not possible, the bottle should be rinsed with cold water in several changes;

- the use of glass bottles is another alternative, but it is important to manipulate them carefully to avoid breakage and injury.

NOODLES emphasizes that the above activities on the use of BPA baby bottles represent health prevention measures adoptable by the general population, as well as by parents already feeding their babies using BPA bottles. A low BPA exposure does not imply by itself health consequences: “is the dose that makes poison”, so let’s act in order to minimize the BPA intake by infants in the everyday life. As well as for other widespread EDCs, we may not be able to completely live BPA-free but we can limit our BPA consumption and make smart decisions for ourselves and our children’s lives.

BPA exposure is ubiquitous, and current TDI is under intense discussion to assess whether it is really protective to the developing organism. Considering the existing areas of uncertainties and potential higher exposure in the sub-Saharan African scenario, preventive measures to minimize children intake should be taken. From a public health standpoint, prevention of exposure to today’s contaminants in small children will help support a healthy adulthood.

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# **TRAINING THE TRAINERS FOR CAPACITY BUILDING IN HEALTH INFORMATION PRODUCTION AND DISSEMINATION IN AFRICA ON THE BASIS OF THE NECOBELAC EXPERIENCE**

Paola De Castro, Daniela Marsili, Elisabetta Poltronieri  
*Publishing Unit, Istituto Superiore di Sanità, Italy*

## **Introduction**

Timely access to high-value information on health has always been crucial for all stakeholders, from researchers and practitioners to decision makers and also to the general public. The appropriate production and dissemination of information to different targets is a crucial component of research activity, but very often scientists do not have the appropriate skills and/or tools to outreach and disseminate the information they produce (1, 2). This bottleneck is even more relevant in less economically developed countries, where training in scientific writing is difficult to achieve and the Information Communication Technologies and associated infrastructures are not so widespread as they would deserve.

In line with the initiatives aimed at gaining unrestricted availability of research results worldwide, the European Project NECOBELAC (Network of Collaboration Between Europe and Latin American-Caribbean countries), funded under the EC FP7 for the period 2009-2012 and coordinated by the Istituto Superiore di Sanità (ISS, the National Health Institute in Italy), has invested efforts to develop a training strategy on scientific writing and open access publishing models in the field of public health (3-5). The main goal of the NECOBELAC project ([www.necobelac.eu](http://www.necobelac.eu)), in fact, is to foster a dynamic process of capacity building in health information production and dissemination at different levels, with special focus on the opportunities provided by the Open Access (OA) publishing model. Sustainability and adaptability of the NECOBELAC training strategy allow its adoption in other geographical areas such as African countries.

## **Critical issues of information resources in Africa**

Innovation in Information and Communication Technology (ICT) resources plays a pivotal role for the spreading and sharing of knowledge, which are essential to accelerate development in science and thus to promote wellbeing for people. Nevertheless, the access and use of Internet globally highlight a digital divide not yet filled.

The most recent Science report 2010 (6) of the UNESCO (United Nations Educational, Scientific and Cultural Organization) contains detailed information on the Internet access in the different Regions of the world. Data refer to the increase of Internet users per 100 population in the year 2002 against 2008 and shows a global upward trend from 10.77 in 2002 to 23.69. Although a positive trend is registered worldwide, regional differences are relevant as well as differences among sub-areas in each Region. According to this report, Internet users in Africa increased from 1.20 per 100 population in 2002 to 8.14 in 2008, in Europe from 24.95 to 52.59,

in the Americas from 27.68 to 45.50, in Asia from 5.79 to 16.41 and in Oceania from 43.62 to 54.04. We report here several selected data that appear on the UNESCO's report to highlight differences among sub-areas within the regions of interest (Table 1).

**Table 1. Internet users per 100 population in the years 2002 and 2008**

Continents	2002	2008
Europe	24.95	52.59
European Union	35.29	64.58
Americas	27.68	45.50
North America	59.06	74.14
Latin America and the Caribbean	8.63	28.34
Africa	1.20	8.14
South Africa	6.71	8.43
Sub-Saharan countries (excl. South Africa)	0.52	5.68
Arab States in Africa	2.11	16.61

The most recent *Little Data Book on Information and Communication Technology 2012* (7), a joint publication between the World Bank and the International Telecommunication Union, provides statistics on the ICT sector for 2005 and 2010 with regard to 216 economies around the world. Data in percentage referring to the indicator "Individuals using the Internet" shows a global upward trend from 15.8 in 2005 to 30.2 in 2010, thus confirming the increasing growth of access to ICT reported by the above mentioned UNESCO Science report 2010 comparing 2002 against 2008 (6). Although a positive trend is registered worldwide, regional differences are relevant as well as differences among sub-areas in each Region. According to this book, data relating to Africa, whose countries are grouped under two broad regions named as Middle East & North Africa and Sub-Saharan Africa, Internet users increased from 10.6 in 2005 to 32.3 in 2010, while in Europe & Central Asia they grew from 12.9 to 39.3, in Latin America & Caribbean from 16.5 to 34.0, and in East Asia & Pacific from 8.3 to 29.8.

Despite the advantages coming from the use of Internet technologies and advanced tools for information provision are widely recognized, in some countries Internet users are very limited, access is still quite poor, and connections may be really very slow. As a consequence, accessibility to scientific research as conveyed through electronic publications is inevitably modest as it represents a reality affordable solely in a digital environment.

If, on the one hand, the absence or limited availability of Internet connections in Africa prevents easy access to valuable information, on the other, a large portion of valuable research is not published mainly due to lack of skills in scientific publishing, of financial support to pay for publication fees, and/or the existence of language barriers. Here we discuss some of these limitations. In general, African research papers are under-utilized, under-valued and under-cited in the international and African research arenas. Therefore, it is very common that valuable information does not reach the people who need it.

### Information discrimination

Thanks to the achievements of the OA movement, there is a powerful potential to fight against information discrimination from the South to the North and vice versa. Once again, the solution towards a really free flow of scientific information worldwide must rely on the efforts of all stakeholders acting in the information, education and dissemination fields. All these actors of scientific communication are called to build up solid national and international partnerships



to enhance transfer of knowledge for the benefit of societies. Key challenges to be tackled in sub-Saharan African countries are mainly related to the development of ITC strategies and to improve technical skills making human resources available as a necessary initial condition to overcome the weakness of local infrastructures. The mentioned UNESCO Science report 2010 contains a detailed analysis in this regard (4).

## Language barriers

Besides the issue of progress in information technology as an accelerator in accessing scientific research, there is another crucial aspect to be considered: the language. English is the language of science as well as the language of science in Internet. At the same time English language represents a barrier to knowledge for non native-speaking countries around the world. This means that also in sub-Saharan African countries, as in other parts of the globe where English language is not dominant, there is a loss of linguistic and cultural diversity and local knowledge. This fact represents a serious concern both for policy-makers at local level, who invest on innovative ICT solutions based on the use of English, and for researchers who cannot easily access to science mainstream journals if not skilled at English. (8)

## The OA model

Making research results accessible for all, regardless of financial, legal and technical barriers is the key principle supporting the OA strategy worldwide. More precisely, scholarly communication based on the OA paradigm lead scientists and their institutions to get immediate and free access to the scientific literature they produce, either by publishing in OA journals or by posting research papers on OA institutional repositories (9).

OA journals are journals that use a funding model that does not charge readers or their institutions for access, as defined in the Directory of OA Journals (DOAJ – [www.doaj.org](http://www.doaj.org)). This directory aims to increase the visibility and ease of use of OA scientific and scholarly journals therefore promoting their increased usage and impact. In this way, the users have the right to read, download, copy, distribute, print, search, or link to the full texts of the articles of these journals.

A search performed on November 2012 in DOAJ show the inclusion of 470 African OA journals over a total of 8.395, of which a surprising 4.16% (349 journals) come from Egypt. Table 2 shows the geographical distribution of African OA journals in DOAJ in 2012 in all disciplines. It is important to consider that in 2002 no OA African journals, except 3 relating to Egypt, appeared in DOAJ.

Besides DOAJ which is an international directory, it is worth mentioning another important initiative that includes only OA African Journals: the African Journals On Line (AJOL <http://www.ajol.info>). It is an online service providing access to African-published research aiming to increase worldwide knowledge of indigenous scholarship. AJOL is a Non Profit Organization based in South Africa. The idea supporting the creation of this initiative is that “online academic resources from the developed Global North are made available to Africa (such as HINARI, AGORA and OARE), there needs to be corresponding online availability of information from Africa. Important areas of research in Africa are not necessarily covered by publications from the developed world. African countries need to collectively play a greater role in the global online scholarly environment. African researchers also need access to their own continent’s scholarly publications.” Up to date (November 2012), the AJOL includes 139 OA journals over a total of 442 journals.

**Table 2. Geographical distribution of African OA journals in DOAJ in 2012 in all disciplines (November 2012)**

Country	2012
South Africa	54
Egypt	349
Nigeria	26
Tunisia	10
Kenya	6
Morocco	6
Uganda	4
Ethiopia	5
Tanzania	4
Ghana	2
Libya	2
Madagascar	1
Lebanon	1
Total	470

The Academy of Science of South Africa ([www.assaf.co.za](http://www.assaf.co.za)) through its Scholarly Publishing Unit takes responsibility for ensuring that OA initiatives are promoted to enhance the visibility of all South African research articles and to make them accessible to the entire international research community.

The Academy recognized that the work published in local African journals must become more visible through search engines and bibliometric tools. Agreements were taken to be included in the Scientific Electronic Library Online (SciELO, [www.scielo.org](http://www.scielo.org)) which has been in development in Latin America since 1997 (8). SciELO is a model for cooperative electronic publishing of scientific journals on the Internet providing an efficient way to assure universal visibility and accessibility to their scientific literature, thus contributing to overcome the phenomena known as ‘lost science’ collection. The SciELO system is now operating in 15 countries from Latin American and Caribbean, Spain, Portugal and South Africa, indexing and publishing a vast array of peer reviewed journals and recently covering also scholarly books.

At present the SciELO South Africa collection includes 23 titles (all disciplines) over a total of OA 985 journals (November 2012). Since 2010 the scientific journal of the ISS, *Annali dell’Istituto Superiore di Sanità* ([www.iss.anna](http://www.iss.anna)) was included in the SciELO Public Health collection (<http://www.scielosp.org/>).

Broadening access to scholarly literature by publishing on OA journals implies a cost that could be expensive. On one hand scientists often argue they cannot afford paying for high publication charges required by publishers, on the other hand OA publishers claim their journals are appealing as they use peer review to ensure a high scientific standard as well as traditional journals with locked contents do.

However, it is worth mentioning that apart from the most prestigious OA publishers such as BioMedCentral (presently including over 214 peer reviewed OA journals) and PLoS (Public Library of Science: <http://www.plos.org/about/index.php>, including 7 OA peer reviewed journals), there are many other OA journals, who do not require payment for publication fees. Many OA journals use free software for the editorial management, such as the Open Journal System (OJS: <http://pkp.sfu.ca/ojs-journals>) currently including over 7500 titles, and this helps them reducing publication costs directly affecting the amount of publication fees by the authors.

In addition OA journals offer facilities that accelerate the circulation of a paper in the Net thus permitting to evaluate its impact by adopting new metrics as Web impact factor, citation analysis (download statistics) and usage factors.

Furthermore, many researchers still believe that OA journals do not have impact factor, so they still prefer to select traditional channels of publication. On the contrary, there are now many OA journal acquiring high values of impact factor, such as the *Journal of Medical Internet Research* (JMIR), a leading peer-reviewed journal in the field of e-health is now ranked the top journal in the medical informatics category (out of 20 journals), and second in the health sciences and services category (out of 62 journals), by Impact Factor (<http://www.jmir.org/announcement/view/24>).

Another way to help circulation of scientific documents with limited costs is represented by the use of digital archives or repositories. Repositories permit to manage and store digital content at different stages in the publication process (before and after peer review), taking into consideration copyright restrictions. Putting content into an institutional repository means to make research results freely available online to the whole research community and other potential users of the research literature. Thus, repositories represent a means for authors and their institutions to keep control of their own scientific production free from the monopoly and pressure of publishers on the scholar and academic community. As far as information resources available for the scientific community in Africa are concerned, a search performed in November 2012 on Registry of OA Repositories (ROAR, <http://roar.eprints.org/>) resulted in 1.99% (no. 60) repositories over a total of 3017. The same search performed in the Open Directory of OA Repositories (OpenDOAR, [www.opendoar.org](http://www.opendoar.org)) resulted in 2% African repositories (no. 58) on a total of 2233 all over the world.

As far as the increasing role that African countries can play within the OA global scenario is concerned, South Africa hosted the Berlin 10 OA Conference (the Conference was held at the Wallenberg Research Centre, Stellenbosch, Institute for Advanced Study (STIAS) from 7-8 November 2012). The challenging theme of the Conference was “Networked scholarship in a networked world: participation in Open Access”.\*

## The training experience of the NECOBELAC project

In order to contribute to the promotion of unrestricted availability of research results worldwide, the NECOBELAC Project has developed a training strategy on scientific writing and OA publishing models in the field of public health. Currently the geographic areas of the interest for the Project are represented by Europe and Latin America. The main goal is to foster a dynamic process of capacity building in health information production and dissemination, raising awareness on the opportunities of the OA publishing.

In order to maximize its impact, the NECOBELAC training methodology envisages two levels of training activities: training for trainers (T1) and the replication of the training activity at local level (T2). NECOBELAC partners and local experts are the teachers in the training courses for trainers (T1) on scientific publishing, which includes both scientific writing and OA.

The participants in T1 courses become the new NECOBELAC trainers to be involved in the capacity building process which is intended to reach an ever increasing audience of individuals and institutions. The approach conceived to achieve this goal consists of spread of knowledge, awareness, participation and responsibility in creating quality health information resources in view of immediate, open and permanent access to research outputs. Accordingly, the training

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\* During the Conference two new platforms were launched for OA journals and for repositories.

activity at local level (T2) consists of training for non-experts, performed by participants in the T1 courses the NECOBELAC new trainers – assisted by project partners and local experts (Figure 1).

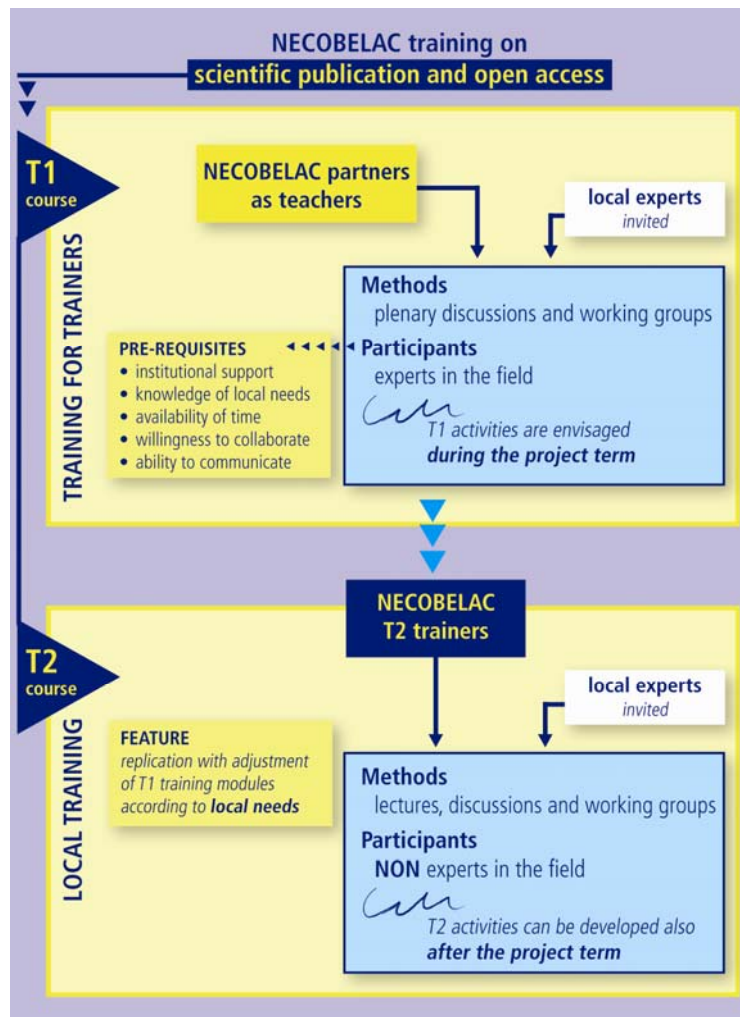


Figure 1. The NECOBELAC training methodology scheme

NECOBELAC provides selected online training material and tools for both the two training levels such as the Guide for trainers, the list of Frequently Asked Questions, promotional material, as well as the NECOBELAC topic maps on “Scientific Publishing” and “Open Access”. Such maps are based on the semantic web technology (<http://code.google.com/p/ontopia/>) and represent information using “topics”, “associations” and “occurrences”. The NECOBELAC topic maps consist of different modules on the project training contents, each one having a textual description, a scheme and links to selected online resources. This online tool was selected for its flexibility and therefore adaptability to different local training requirements.

The final results of the NECOBELAC training activity consist of training courses for trainers (T1) performed in Brazil, Italy, Colombia, Spain, Argentina, Portugal, Mexico and Ireland as

well as of 40 training activities at local level performed both in European and Latin American countries (the whole project's training activity envisaged 8 training courses for trainers, 4 in Latin America and 4 in Europe, with an average of 30 participants per course for a total of 240 NECOBELAC trainers and the target has been set to have 1000 participants in the T2 activities). The methodology of training courses (T1 and T2), facilitated by the available online NECOBELAC resources and tools, allows the further increase of the number of benefiting institutions and individuals also beyond the Project conclusion (July 2012).

In order to adequately apply the NECOBELAC training strategy in other geographical areas and contexts such as African countries, it is useful to highlight some important issues concerning methodology and contents, which rely on the training experience achieved so far.

First of all the selection of participants in training courses for trainers is crucial to guarantee replication of the training activities at local level with the support of their institutions; nevertheless the new trainers need to be supported by the core partners operating in their geographical area for replication of courses at local level.

Second, the contribution of local experts in the training courses creates a major involvement at local level and helps to balance international quality standards in public health production and dissemination with local practices and priorities.

Third, within training courses for trainers the working groups represent a useful tool for active learning, participation, and result in planning feasible training programs at local level. Moreover, useful information on national and local practices and initiatives provided by participants in both T1 and T2 courses helps to highlight differences and common requirements.

Last but not least, printed material concerning training, contents and online resources provided by the project of the training program helps the participants of training activities to become able to manage the new knowledge. At the same time, ad hoc promotional printed material on the training program helps the new trainers for the organization of local training initiatives.

A detailed description of NECOBELAC project and training activities, including the topic maps topic maps on scientific writing and OA publishing are included in the are the cited *Rapporti ISTISAN 12/26 (5)*.

## Final considerations

The NECOBELAC training strategy, programs and contents are the results of complementary skills and experiences of the European and Latin American partners. The adoption of such a bi-directional approach, addressed to gathering common objectives, represents a key factor of this successful scientific and technical cooperation. In this way, we envisage a cooperation framework able to add value to local informative resources, to promote a grounded inclusive environment for health professionals, researchers, information specialists and local authorities in order to better address training local needs.

The NECOBELAC training methodology and online contents guarantee sustainability of the initiative embedding flexibility and adaptability to different local contexts and geographical areas and countries not initially covered by the NECOBELAC project such as African countries also considering that a number of scientific collaboration initiatives are already established among Italy (ISS) and other health institutions in Nigeria, Cameroon (as described in the other chapters of this volume). Thus, we propose to contribute to this interdisciplinary cooperation framework, where the shared commitment to strengthen research capability in public health, including the improvement of information production and dissemination of health information, can foster the improvement of population health.

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## **AFRICA AND SCIENTIFIC “PREVENTION, EDUCATION AND RESEARCH” NETWORKING: CONCLUDING REMARKS**

Chiara Frazzoli (a), Emmanuel Acha Asongalem (b), Orish Ebere Orisakwe (c)

(a) *Department of Veterinary Public Health and Food Safety, Istituto Superiore di Sanità, Italy*

(b) *Faculty of Health Sciences, University of Buea, Cameroon*

(c) *Faculty of Pharmacy, University of Port Harcourt, Nigeria*

Health protection and promotion depends heavily on risks perceptions and hazards awareness among stakeholders, policy makers, health workers and scientists. Networking provides a strong driver in promoting multidisciplinary interaction, creative participation and community formation around health and prevention issues. In particular, Africa is overall a data-poor continent; therefore, risk analysis in the African context can be extremely difficult due to so many uncertainties as well as so many risk factors that are poorly known and/or controlled. Risk analysis integrates the components of risk assessment, risk management and risk communication: its development needs proactive role of local communities in shaping information, especially when the continent's problems are looked out of context. Networking can greatly help in exploiting human, cultural and resources to generate new knowledge and understand risk scenarios.

The Internet aims at enabling all to take advantage of a globalised world. Its role in sharing and disseminating scientific knowledge needs not be reaffirmed: but the web can do more than this. Social media such as Facebook and websites fall under new media and should be used to boost scientific development. The power and popularity of social media (e.g. photos and videos shared via the web) can generate interesting information on real-life scenarios for risk analysis to share with the Network.

The impressive performance of the web cannot overshadow the role of more conventional media. Town meetings, TV, broadcasting and newspapers are still essential to reach majority of the population; scientific journals (e.g. the African journal of Toxicological Sciences) are necessary to build up a scientific community pivoting around African issues. Instruments for scientific dissemination (e.g. *Prevention Without Borders*, newsletter of the Noodles network) can provide the link between different societal and scientific components of the Network; indeed, they can effectively help building the cultural and organizational conditions to let the themes of this report working effectively and efficiently.

The Indian lesson reveals how “better educational outcomes are a strong predictor of economic growth” (1, 2). The OECD PISA study shows that an image of a world divided neatly into rich and well-educated countries and poor and badly-educated countries is out of date. OECD findings show that poor skills are not an inevitable consequence of low national income: an important outcome indeed for countries that need to achieve more with less. The study indicates that significant results can be achieved with limited economic resources in diverse social contexts; in fact Countries from a variety of starting points have shown the potential to raise the quality of educational outcomes substantially (2).

So far the European Union (EU) research funding has been a pivotal avenue to partnership with EU researchers. As Subra Suresh (US National Science Foundation NSF Director) points out, *Good science anywhere is good for science everywhere*; research fields of international

dimension will benefit through cooperation and will lead to research findings towards sustainable benefits for the public at large.

For instance, in the EU Seventh Framework Programme (FP7) grants for the period 2010-2012, researchers engaged in investigating a number of themes, including fisheries and biotechnology, were required to collaborate with at least one scientific partner from Africa.

The mandate for EU research groups to include African partners in projects was dropped from the FP7 2013 calls for proposals for EU competitive research grant (3). Some concern is justified that in the absence of a specific mandate, EU researchers will have limited incentive to seek collaborators in Africa; this might be also enhanced by the current criteria for young scientists' careers evaluation, e.g. highly scored publications in international journals, that may be expected to be produced more easily from collaboration with USA or Eastern Asian partners (3). Moreover, research in most developing countries may be weakened by the lack of the administrative support available in developed countries; in its turn, this would lead to challenges in "getting the reports in on time and in getting the finance" which is a mandatory requirement for successfully fulfilling EU grants (3). The added strength of networking will, therefore, support the international role of African research, especially in such complex and difficult areas as veterinary public health and food safety.

African researchers have to identify in international consortia themes relevant for them and on which they can add value with their work. Africa can take charge of how its scientific activity is viewed globally in order to attract collaborations; a further strengthening point would be reinforce south-south collaboration and networking with extra-African actors. As ultimate goal, like EU Africa might envisage to launch its own international research programmes, identifying needs and values that primarily require the support of new knowledge.

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