Environmental inequities and low birth weight

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Summary. - The effects of environmental exposures to toxic agents, are related to different levels of exposure, genetic and biological susceptibility, risk perception and socioeconomic status (SES). In the present study we suggest that environmental influences on human reproduction should include investigations on SES, that can play an important role in embryo-foetal development. Low birth weight (LBW) is a risk factor for developing in adulthood coronary hearth disease, hypertension and type 2 diabetes. Maternal nutritional status and other hypothesis could explain LBW, however, environmental exposures are recognised as essential risk factors. Different studies evidenced an increased risk of LBW in relation to increased environmental air levels of particulate matter, carbon monoxide, and sulphur dioxide. Considering different risk possibilities and different risk perceptions, there is a need of a different scientific approach in which the scientific knowledge is connected with ethical and socioeconomic factors, for risk management, in order to overcome the environmental health inequities based on social contest.

Key words: environmental inequities, low birth weight, ethics, socioeconomic status, air pollution.

Riassunto (*Iniquità ambientali e basso peso alla nascita*). - Gli effetti prodotti dalle esposizioni ad agenti tossici ambientali, dipendono sia dai differenti livelli di dose assunta, dalla diversa suscettibilità genetica e biologica individuale, che da una differente percezione del rischio e da differenziate condizioni socioeconomiche. Nel presente lavoro vogliamo suggerire che le influenze ambientali sulla riproduzione umana dovrebbero includere indagini su tali condizioni, poiché queste possono avere un importante ruolo sullo sviluppo embrio-fetale. Il basso peso alla nascita (BPN) è un fattore di rischio per lo sviluppo nell'età adulta di patologie cardiovascolari, ipertensione e diabete tipo 2. Molte ipotesi, come lo stato nutrizionale materno, possono spiegare il BPN, ma in ogni caso le esposizioni ad inquinanti ambientali sono state riconosciute come fattori essenziali di rischio. Diversi studi hanno evidenziato un aumento di tale rischio, quando nell'aria c'è un incremento dei livelli di particolato, monossido di carbonio, e anidride solforosa. Considerando le varie possibilità di rischio e le differenti percezioni di esso, si ha sempre più bisogno di un diverso approccio con cui poter collegare le nostre conoscenze scientifiche a considerazioni etiche e socio-economiche ed affrontare e ridurre quelle iniquità ambientali sulla salute sostenute da diversi e differenziati contesti sociali.

Parole chiave: iniquità ambientali, basso peso alla nascita, etica, condizioni socio economiche, inquinamento dell'aria.

Introduction

A common and general definition of environment includes all influences which alter and modify the status and the relationship between the living systems and the outside world. This outside world is not confined within the boundary of biotic or abiotic elements because for human beings the environmental influences always include cultural and social relationships. The geographical differences in the distribution of environmental pollution are the first we have to consider in analysing the distribution of human diseases. But social distribution of pathologic outcomes is always associated not only with chemical, physical (*the abiotic* *world*) or biological *(the biotic world)* environmental exposures but also, more frequently, with social determinants *(the cultural world)*. Health is the adaptive process between these dynamic related *worlds* [1, 2], and the social determinants of the *cultural environment* have a particular effect on human health status [3] (Fig. 1). The relationships between socio economic differences and unequal exposures to environmental sources of pollution help understanding the differences in rates of diseases.

Often when we analyse epidemiological studies, besides sex, gender and ethnicity, socioeconomic status (SES) is associated with pathologic susceptibility to many adult diseases [4-7]. The SES is a descriptive

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term for an individual's position in society, which describes the educational level attained, occupation, income and value of dwelling place. Here we want to consider outcomes on human reproduction associated with the long term risks with the future adult human health. The different access to educational opportunities and to health care quality services, the personal choices and life styles in the social organization, the work place and the technological world play a significant role in the socioeconomic association with health status. Gender, ethnicity, cultural patterns, and life cycle periods are also connected with social opportunities.

The human life cycle determines a differential susceptibility to different pathologies and depends at first on the intrauterine development in which the process of biological foetus programming and the maternal nutritional status may contribute to an additional risk in adulthood health status. The perinatal period is the most important stage of the life cycle and for that reason epidemiologists use mortality and birth weight rate as a fundamental health index of a defined population [8]. Recently it was recognised that foetal development and the subsequent size at birth are often determinants for the higher susceptibility to adult chronic diseases such as hypertension, coronary heart disease and type 2 diabetes [7, 9, 10].

In order to identify the hazard and to evaluate and prevent the associated risk of impaired foetal development with different susceptibility, qualitative, economical and ethical considerations need to be implemented in risk management [4]. Very often health inequalities become inequities, because they are unnecessary as they could be avoidable. A new different approach should therefore connect the observed scientific data with social and economic factors and, in order to solve the health inequalities, which become inequities when based on the modifiable social contest,



Fig. 1. - Dynamics of biotic, abiotic and cultural environmental influences on human health. Modified from McElroy and Townsend, 1996 [1].



Fig. 2. - Possible risks due to exposure of pregnant women to indoor and outdoor air pollutants in urban environments. Modified from ALA, 2001 [5].

we need to consider an ethical point of view. Today the toxicological reflection on historical evolution of the environmental assessment process [11] can no longer consider the susceptibility of individuals or different groups or subgroups or community, without taking into consideration their social, cultural or economic relationships.

Case study: low birth weight at term

Embryo-foetal development is the first period of the human life cycle; it begins at conception and ends with delivery. During this period the foetal programming process is influenced by many environmental factors which may have particularly adverse effects especially during critical periods. Low birth weight (LBW) is considered a sensitive indicator of adverse effects during pregnancy. In this paper we try to examine the connection between air pollution, mother's socioeconomic status and the development of LBW, by examining epidemiological studies carried out in both developed and developing countries of the world. LBW is a weight of less than 2500 g at birth. It is a major public health problem world wide and a significant determinant of postnatal mortality and morbidity. Recent research suggests that several of the major diseases occurring late in life, including coronary heart disease, hypertension and type 2 diabetes, originate in impaired intrauterine growth and development [7, 9]. The influences that impair foetal

Indoor and outdoor air pollution exposure	IUGR	LBW (< 2500 g)	Authors
со	Associated (marginally)	Associated Associated	Boy, E. <i>et al.</i> , 2002 (Guatemala) [16] Maisonet, M. <i>et al.</i> , 2002 (North-east, USA) [18] Ritz, B. and Yu, F., 1999 (Southern CA, USA) [21]
SO ₂		Associated Associated Associated Associated	Bobak, M, Leon, D.A. 1999 (Czech Republic) [17] Maisonet, M. <i>et al.</i> , 2002 (North-east, USA) [18] Rogers, J. F. <i>et al.</i> , 2000 (Georgia, USA) [20] Wang, X. <i>et al.</i> , 1997 (China) [12]
РМ	Associated Associated Associated Associated		Boy, E. <i>et al.</i> , 2002 (Guatemala) [16] Dejmek, J. <i>et al.</i> , 1999 (Czech Republic) [14] Dejmek, J. <i>et al.</i> , 2000 (Czech Republic) [15] Chen, L. <i>et al.</i> , 2002 (Nevada, USA) [13]
		Not associated Associated Associated	Maisonet, M. <i>et al.</i> , 2002 (North-east, USA) [16] Rogers, J. F. <i>et al.</i> , 2000 (Georgia, USA) [20] Wang, X. <i>et al.</i> , 1997 (China) [12]

Table 1. - Epidemiological studies in which authors correlate IUGR and LBW with by CO, SO₂ and PM air pollutants

IUGR: intrauterine growth retardation; LBW: low birth weight; PM: particulate matter.

growth and development in utero are still unknown. However considering that multifactorial events can affect foetal nutrient demand, several harmful factors have been considered among them: individual genetic susceptibility, dietetic maternal regimen, smoke and alcohol consumption, drug abuse, pathologic, physiologic and psychological status, and any environmental exposure.

In the present study we have considered the possible association between indoor and outdoor environmental air pollution exposure and LBW at term. The importance of environmental air pollution is the involuntary exposure of large urban populations rather than individual voluntary choices. This involuntary exposure is one of the many environmental inequities and is therefore connected to the ethical problems of health policies and specific intervention programs for preventing diseases attributable to urban air pollution (Fig. 2).

Air pollution is a complex mixture of suspended particles and gaseous components. The particulate matter (PM) relevant to human health are the inhalable particles with an aerodynamic diameter equal to or less than 10 μ m. Studies which relate PM, carbon monoxide (CO), sulphur dioxide (SO₂), hydrocarbons (c-PAHs) with intrauterine growth were considered. These are common air pollutants found in both indoor and outdoor environments and are recognized as complex toxic hazards.

Several studies of maternal exposure to major air pollutants during pregnancy are related to the outdoor local presence of traffic, industrial sites, dry cleaners, and gasoline pumps. The social inequality of the different exposure to these air sources of pollution may be greater when we consider indoor air pollution; some groups of people including newborns, youngsters, the elderly or those suffering from respiratory or cardiovascular diseases spend more time than others in confined environments. The most common sources of indoor pollution are related to the social and economic conditions and have shown to have a negative impact on foetal development (Table 1). However, there is ample evidence that SES is a strong determinant of susceptibility to the adverse effects of air pollution [5].

The effects of air pollution on infant birth weight have been recognised only recently in a cohort study in China in which there was an inverse relationship between exposure to PM and SO2 during the third trimester of pregnancy and mean birth weight [12]. In this study the odds ratio for LBW was 1.11 (CI 1.06-1.16) for each 100 μ g/m³ increase in SO₂ and 1.10 (CI 1.05-1.14) for each 100 μ g/m³ increase in total PM. Foetal growth does not follow a uniform pattern and weight growth is predominantly a phenomenon of the third trimester; some studies have found a correlation between PM exposure and LBW during the third trimester of pregnancy such as the study in China [12] and a study in Northern Nevada [13] in which a 10 $\mu g/m^3$ increase in the PM level during the third trimester of pregnancy can be associated with a birth weight reduction of 11 g (CI 2.3-19.8 g), although no association with LBW was found. On the other hand other studies found associations between PM maternal exposure in the first gestational month and intrauterine

growth retardation (IUGR) in a highly polluted area of Northern Bohemia [14]. In this study odds ratio for medium ambient PM concentration was 1.62 (CI 1.07-2.46) and for high PM concentration was 2.64 (CI 1.48-4.71). In a subsequent study the same authors [15] evidenced a relationship between maternal exposure in the first gestational month to polycyclic aromatic hydrocarbons (c-PAHs) usually bound to fine particles and increased risk of IUGR. Adjusted odds ratio was 1.22 (CI 1.07-1.39) for each 10 ng increase of c-PAHs. Prenatal outcomes due to air pollutants exposures are not limited to LBW but can also include IUGR which although less severe than LBW still provides an important contribution to the debate on reducing the exposure to air pollution world-wide [13-16].

There is an extensive list of risk factors for LBW including maternal age, parity pre-pregnancy weight, history of adverse pregnancy outcomes, low social class and cigarette smoking. In order to identify the pollutant responsible for the adverse effect on foetal growth, all the confounding factors which are highly associated with LBW must be taken into consideration. Although the association between SO₂ and LBW is found in several ecological studies, SES is more strongly associated with LBW. The inclusion of SES in these epidemiological studies often reduces the risk of LBW associated to outdoor air pollutants [17]. In an ecological study in the Czech Republic the prevalence of LBW was positively associated with the concentrations of two air pollutants and the crude odds ratios for 50 μ g/m³ increase in SO₂ and NO₂ were 1.21 (CI 1.13-1.30) and 1.14 (CI 1.04-1.24) respectively. The adjustment for the socio-economic characteristic of the district reduced these estimates for SO₂ and NO₂ to 1.10 (CI 1.02-1.17) and 1.07 (CI 0.98-1.16) respectively. In this study LBW was strongly related to socio-economic characteristic and socio-economic factors were strongly associated with LBW [17]. Also in another study by Maisonet et al. [18] the strength of an association between CO and LBW at term was reduced by taking into account most of the known social determinants of LBW. In fact exposures in the third trimester of pregnancy to ambient CO increased the risk of LBW, odds ratio 1.69 (CI 0.97-2.96), the adjustment for maternal age, race/ethnicity, mother's years of education, marital status, gestational age, and adequacy of prenatal care, smoke and alcohol consumption in pregnancy changed the odds ratio to 1.31 (CI 1.06-1.62). In contrast to previous studies, no evidence of an association between LBW and PM was found. Moreover, when data were stratified according to maternal race/ethnicity there was heterogeneity in LBW, i.e. the association of CO with LBW at term was limited to African-American infants, while the effect of SO₂ was more relevant in white infants [18, 19].

Studies have used atmospheric transport modelling techniques in order to better classify environmental exposures, however even with this modelling, epidemiological studies were unable to determine whether the pollutants taken into consideration were causative agents of LBW [20]. All these studies raise a question of uncertainty in the exposure evaluation and the causative association.

Smoking is an important risk factor of LBW and possibly the CO is responsible for the adverse foetal growth [21]. In fact, haemoglobin in foetal blood has 10 times more affinity for binding CO than does adult haemoglobin. In fact several studies found an association between environmental CO exposure and foetal growth retardation [16, 18, 21].

CO is produced during the combustion of tobacco, wood and other biomass. Therefore in developing countries, where two-thirds of households rely on bio fuels as their primary fuel, pregnant women are habitually exposed to high levels of CO. People who use wood for cooking and heating are the poorer members of the community and women using an open fire instead of a chimney stove are even more heavily exposed to PM and CO. It has been recently shown that although there is an association between exposure to indoor bio fuel pollution and reduced birth weight, independent of the confounding factors i.e. SES, in a study in Guatemala respiratory symptoms were strongly associated with the confounding factors, moreover when the SES was defined according to the type of fire used there was a very strong association between the type of fire used and respiratory symptoms [22].

What can then be done for prevention, considering the technical, economic and cultural barriers to achieve substantial exposure reductions in the world's poorest households?

Maternal educational status is correlated to risk perception and risk communication and therefore is part of SES. To increase the risk perception and to communicate the associated risk of indoor air pollution, low maternal educational status, which is highly associated with LBW, needs to be improved.

Conclusions

In identifying risk factors which can determine adverse health effects on human beings, toxicologists have traditionally focused their attention on individual lifestyles, genetic predispositions and specific exposures to environmental pollutants. A risk analysis process bases its assumptions on risk assessment (an objective quantitative dose-related scientific method) and subsequently on a risk management strategy, where political decision-makers consider which measures are necessary to protect the environment and/or human health. Sometimes the perception of the hazard becomes higher than the objective risk and the public loses its confidence in government control systems. Two good examples of this mentioned risk communication/perception, are dioxin food pollution and bovine spongiform encephalopathy.

Now we can consider that social and cultural factors such as SES are considered "fundamental causes" of environmental inequities and public health status [2, 23]. LBW is a multifactor disease resulting from multiple mechanisms [24-26], and both indoor and outdoor pollutants can influence its incidence [27-32], but the assumption that environmental influences are still considered a "normal science", as stated by Kuhn [33], cannot be used anymore.

The post-normal science approach as proposed by Funtowics and Ravetz [34-36] is now more useful when evaluating the effects of environmental influences and assessing how social and economic factors become the causal pathway of health effects before birth. Moreover, SES can have a different impact within different stages of the life cycle, "... life cycle is fundamental to the study of health status because it is the basis of biological change in all individual organisms. It can be divided into age segments during which different types of diseases or conditions are predominant" [8, 37]. Quality becomes more crucial than quantity when there is a high degree of uncertainty, disputed values, conflicting results, high stakes and the decision is urgent. The management of complex natural systems for "non quantifiable risk" requires that the "normal" toxicological approach becomes a "post-normal" approach in which the still essential role of scientific risk assessment should include ethics. Strategies for reducing health inequities, originating from a different distribution of risks, which generally affect particularly weaker subgroups at different stages of life, need to be explored [4, 38].

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