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THE ROLE OF SCIENTIFIC RESEARCH IN THE DEVELOPMENT OF OCCUPATIONAL HEALTH SERVICE

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Introduction

The role of scientific research in the development of occupational health service is presented by the activities of the Institute for Medical Research and Occupational Health in Zagreb. The Institute was founded in 1948 by the Yugoslav Academy of Sciences and Arts as the Institute for Industrial Hygiene. The proposal for the foundation of the Institute came from Professor A. Štampar, the then President of the Academy. At that time Yugoslavia had began its transition from a backward agricultural into an industrial country. The newly created Institute, as a scientific institution, was endowed with a task:

1) to conduct studies and research into physical and biotic conditions of work and into general problems of industrial hygiene in Yugoslav industry;

2) to make it possible for government authorities and for all interested institutions to avail themselves of its scientific and research results for their practical application, and

3) to spread knowledge and information relating to industrial hygiene.

The work of the Institute started with the following units: Psychophysiology of Work, Pathology of Work, Analysis of Biological Material, Industrial Toxicology and Industrial Hygiene.

In the following years some changes took place in the organization and activities of the Institute. The Yugoslav Academy decided to incorporate into the Institute some of its other units and laboratories engaged in medical research. On the other hand the Institute developed its own research in the field of physiology, biophysics, biochemistry, radiobiology and radiological protection. So, apart from the sphere of industrial hygiene and occupational health the Institute's tasks included organizing and conducting scientific research in a wider field of medical and related sciences. In essence, the activity of the Institute — apart from investigating the effect of chemical and physical agents of work environment on health — was directed to the study of the biological effects of various factors in man's environment. Due to the effected changes and activity outline decided upon in the meantime the Institute changed its name in June 1959 to the Institute for Medical Research and Occupational Health. Since 1970 the University of Zagreb has been acting as the Institute's co–founder. A more detailed presentation of the founding and growth of the Institute was described earlier [1-3].

At present the work of the Institute is carried out in three sections: Experimental biomedicine (seven subunits), Environmental hygiene (three subunits), and Clinical and epidemiological studies (five subunits).

At the end of 1983 the Institute had a total staff of 247, 106 of whom with a university degree (physicians, chemists, biochemists, chemical engineers, biologists, physicists, psychologists, electronic engineers).

Programme and accomplishment of main research activities

The studies of the *toxicology of metals and mineral metabolism* date from the time of the Institute's foundation, but the approach in investigations has changed with time. From the very beginning the Institute's main research interests lay with analytical studies of metals, physical and chemical properties of metals in solutions and metal toxicology [4, 5]. Initially, studies of metal toxicity mainly concerned occupational diseases [6, 7], but later they were extended to the effects of metals on human health in general. The investigations in this field mainly concern the pharmacokinetics and toxicity of lead, cadmium, manganese and mercury. They have been conducted with the aim of finding out whether infancy, pregnancy and lactation are periods of increased risk from environmental contamination with metals [8, 9]. Such data are required for setting up standards for permissible concentrations of metals in man's environment. Particular attention has been paid to the effect of diet on the metabolism of metals.

During the years of growing application of nuclear energy the Institute carried out investigations in the field of radiological protection [10] and expanded research to the metabolism of some fission products from the point of view of internal contamination and decontamination [5, 8, 11]. Most of the radiotoxicological studies have been dealing with the metabolism of radioactive strontium and with the testing of complexing substances and their applicability for enhancing radiostroncitum elimination from the body. In collaboration with the Public health service the Institute has undertaken investigations of calcium metabolism with special respect to osteoporosis [12, 13], and more recently, of the metabolism of essential elements — zinc, iron and copper [11, 14].

Toxicological studies of pesticides mainly concern pesticides from the group of anticholinesterases and chlorinated hydrocarbons [15]. In the last few years research has been extended to pyrethroid pesticides. The effects of pesticides have been studied in humans, animals and at molecular level (interaction with enzymes). Analytical methods have also been developed which are applicable to pesticide residues in the environment [11]. Studies on the role of mycotoxins, particularly ochratoxin A, in the etiology of Balcan endemic nephropathy have also been carried out [11].

Initially, studies in the field of *atmospheric pollution* dealt with methodological and field investigations of noxious substances in the workplace environment [16]. In the meantime the field of research was extended to the outdoor atmosphere of urban and rural areas and then to the problem of the biological significance of air pollution with special emphasis on a realistic assessment of the total exposure of people or population groups to a particular atmospheric pollutant. The problem of personal exposure assessment was first encountered when trying to establish biological significance of lead for population groups with different exposure patterns: workers occupationally exposed to lead living in clean areas against those living in polluted areas and against the population of the two areas without occupational exposure. It was obvious that only average total 24-hour exposures can be compared. Therefore, in addition to occupational exposure and to lead levels in the outdoor air in the residential areas, lead in indoor air samples from typical buildings (homes, offices, restaurants) was also measured as well as personal exposure of people doing their jobs in the streets. Taking into accout the time spent, and average concentration in each situation, a model was developed for estimating the weighted average weekly exposure of population groups with a similar time/motion pattern [11, 17]. The model was later adapted for other pollutants.

Studies of the *environmental effects of radiation* started with investigations of the effects of UV radiations on cells in cultures. Later they were extended to the control of X–radiation and radiations from high sources and to the control of radioactive contamination of the environment. The cytogenetic effect of small doses of ionizing radiation and of different chemical mutagens has been studied in cells in culture as well as in group of occupationally exposed subjects [10, 11]. A number of methods for the determination of radioactive elements in human urine have been developed.

Studies in the field of the *psychophysiology of work*, which originally were focussed on physical effort [18], later became more oriented to man's mental and psychomotor efficiency. Research has been carried out on health and safety implications of diurnal variations in tolerance to stress. The relationship between some personality characteristics and the degree of workers' adjustment to shift work has also been studied [11, 19].

Research work in the field of *occupational diseases and clinical toxicology* was first directed to intoxications with heavy metals (lead, mercury, manganese) and the early diagnosis of these intoxications [6]. The reason for this lay in the development of metal manufacturing industry, and at the same time in the growing problems of occupational pathology. Later, many other problems were studied such as neurological manifestations of arsenic poisoning, clinical and subclinical effects of carbon tetrachloride and some other chlorinated hydrocarbons, vinyl chloride exposure and liver function, respiratory impairment in potroom workers, biological significance of low level exposure to carbon monoxide, extrinsic allergies, syndrome of allergic alveolitis, vibration disease, early diagnosis of pulmonary and pleural asbestosis, factors involved in the development of progressive massive fibrosis in coal dust exposure, etc. Some specific aspects of lead toxicology (effect on the kidneys, peripheral neuropathy, effect on reproduction), and manganese exposure effect on respiratory organs, dose–response relationship and neurological effect have also been dealt with [11, 20]. These studies included workers as well as the inhabitants of areas contaminated with emissions from the plants.

From 1950-1983 about 10,000 patients were hospitalized in the Institute's clinical ward and about 80,000 workers suspected of having an occupational disease were examined in the Institute's outpatient clinic. At present workers' morbidity in Yugoslavia probably corresponds to that which can be expected in other countries with similar industrial structure and development. The annual rate of registered occupational diseases is about 1/1000 employees and they participate with about 0.5% as causes of sick leaves [21].

In addition to occupational diseases, studies of workers' morbidity, absenteeism and disability in relation to *chronic degenerative diseases* have been conducted. Attention was first focussed on improving the methods for the study of workers' morbidity caused by chronic degenerative diseases, on their early diagnosis and risk factors which are associated with the development and occurrence of some of these diseases [22]. Later on, applying current epidemiological methods, the prevalence of chronic diseases and a possible connection between occupation, *i.e.* conditions of work and occurrence of some of the diseases have been investigated. The studies performed in workers exposed to different dusts, showed that even chemically or physically inert dusts, in conditions of long exposure, play an important role in the development of chronic nonspecific lung disease. A part of the studies conducted concerned the distribution of blood pressure values and arterial hypertension in segments of industrial population. Degenerative diseases of the joints and spine, with regard to occupation and physical load have also been studied [11, 23, 24].

In the meantime studies on chronic diseases have been extended to groups of general population [11, 25, 26].

In the sphere of human ecology, during the last ten years, *anthropological studies* of continuous morphological and physiological traits have been carried out. They have been concerned with two problems: the population structure of isolated population groups and analysis of dermatoglyphic traits in the selection of so-called high risk groups [11, 27-29].

The funds necessary for carrying out Institute's research activities come from research contracts with the Community for Scientific Research and the health authorities, with health insurance agencies, industries and also with a number of foreign organizations such as the US EPA and NIOSH, and international organizations (WHO, IAEA).

Publishing and other activities

From 1948-1983 members of the Institute's staff published 1,417 original papers and communications, 826 technical papers and other publications and submitted 1,107 communications to national and international congresses and meetings.

The Institute has acted as organizer or host to 27 national and international scientific meetings and congresses, including the 19th International Congress on Occupational Health which took place in 1978.

A very important aspect of the Institute's activity is teaching. The Institute takes active part in the graduate and postgraduate teaching programme of the University of Zagreb and acts as one of its teaching bases. Among others, a postgraduate course in occupational health and from this year on a workers' ability assessment course deserve to be mentioned. Since 1980 the Institute has been authorized by the University to conduct examinations of the candidates for M.Sc. and Ph.D. degrees in medical sciences. To date 19 diploma essays, 76 master's theses and 47 doctor's theses have been prepared at the Institute.

The Institute publishes a journal: *Arhiv za higijenu rada i toksikologiju* (Archives of industrial hygiene and toxicology) the only periodical in the field of occupational medicine and environmental health in the country. Two Yugoslav professional associations act as its co-publishers: The Yugoslav Association on Occupational Health and the Yugoslav Association of Toxicologists.

Conclusion

From the presented Institute's activities the following may be pointed out:

1) the work of the Institute has been concerned with current problems arising from industrial development and agricultural modernization. In some cases the problems studied were anticipated, but as a rule they arised from practice. Some problems which arose in the meantime, for example the role of occupation in the appearance of cancer, and biological effects of nonionizing radiations (microwaves and radiofrequency radiation), have been studied only partially or sporadically;

2) some of the Institute's activities are related to basic biomedical studies. Such studies are considered necessary, because they are a basis for applied investigations. In addition, they are important in the education of students and external personnel who during their stay at the Institute acquire knowledge about scientific approach and methods;

3) the ratio between research activities and professional and service activities of the Institute is about 70:30%. From our experience such a ratio seems appropriate. In such an institution, however, adeguate orientation towards research is not the only aim. Transfer of information from and to practice is also very important. It is achieved in different ways: by publishing and distributing results of scientific research, through postgraduate courses in which the Institute participates, as well as by other ways of education, individual relations with experts from industry etc. One specific form of relation also ought to be mentioned here. This is the agreement among relevant institutions regarding mutual cooperation in the field of occupational health in SR Croatia. Two or three meetings of the Council for Cooperation are held every year. Meetings are attended by directors or heads of the most important industrial and other occupational health units. They deal with organization, legislature and other relevant subjects. In this way an influence on legislative and executive authorities is possible;

4) the Institute, which was originally founded to conduct research in the field of industrial hygiene and industrial health, has later expanded its activity to other fields, essentially, to biological aspects of

environmental protection. A question may be raised whether such an institute, dealing both with occupational and environmental health is a right solution.

In our experience it is, because in practice the two aspects, though differing in methodological and other approaches, are often entwined.

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ROLE OF A RESEARCH INSTITUTION IN THE PREVENTION OF OCCUPATIONAL HAZARDS

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The public health institutions, being centers of applied research, can never be isolated from other parts of the society as might be the case of so called autonomous academic institutions. Instead, we have to be sensitive to the problems and needs that have been recognized in our social environment, particularly those of the public and of the authorities, the decision–makers as well as other interest groups. The relations between the public health institute and the social environment are rather complicated, and even in their simplified forms they are difficult to analyze. Fig. 1 describes an operational point of view, for the three main sources of factors which may have an influence on the choices of the priority problems [1]:

A. *Expected*. – This is the zone describing the expectations of the society and its needs concerning our scientific activities, *i.e.*, the needs of the society to get scientific support in solving public health problems (external criteria).

B. *Want*. – This area comprises the motivation of the scientific community that concentrates in the specific problems which are based on our own spontaneous interest (internal criteria).

C. *Can*. – This area describes the organizational, financial, methodological, theoretical and manpower capacities of the institute which undertakes new actions for the solution of public health problems (technical criteria).

Even in the most optimal situation the areas A and B are always larger than C and it must be so; otherwise either the society or the scientific community have lost their strength of progress. The uncoverage of A with B is also important because otherwise the scientific community would loose its role as an important developmental stimulant of the society. Thus the institute would also like to have a bit more and a bit different things to do than those required by the surrounding society. To do only what you are asked to do is not enough for a scientific institute; you must also have your own ideas with which you feed the society. In other words, the external criteria cannot be the only basis of priority setting as cannot the internal criteria either.

The key issue is not, how to get the areas to overlap but how to get problems solved when the areas do not overlap. Unnecessary to say this is a simplified and only an operational model which does not take into consideration numerous nonscientific factors which have their impact as well.

In the institutions where basic research is been done the circles A, B and C may overlap in greater extent though, not even there a researcher is expected to do, he wants to do, and can do only the research he is personally interested in, without any special arrangement. I want to stress that this type of centres for basic research is needed. The public health institutes, however, have a completely different philosophy: they are for the solution of practical public health problems. The spectrum of these problems may vary in extremely wide ranges and requires flexible movement from one research area to another. What is often difficult to understand by the public and by the interested parties, including the decision–makers, is that the subarea 7 is frequently rather small as is the whole circle C when compared to the wide areas of A and B. Usually, we need lots of methodological development and development of the competence of the staff members before the response can be given. As a rule, much effort and time is needed before the response can be given in the cases in which we situate in the subareas 1, 2 or 3 of Fig. 1, *i.e.*, the methodological capacity or scientific competence is insufficient. The experience tells us that the development of manpower capacity for new research areas even in most favourable conditions, takes some 3 to 5 years (often even 10), and the development of a completely new methodology takes 2 to 3 years.

However, less effort and time is needed to create capacity in cases where changes only in the interest and in the priorities of the scientific community or individual scientists are needed (areas C and 4, 5, 6).

Unfortunately, the society and the decision–makers very often believe that directing research to new areas is only a question of changing the interest of scientists. In most cases, however, we have found that the problems are due to the difficulty in keeping a sufficiently high operational capacity (*e. g.*, methodology) which covers the wide area of the public health problems.

To make this analysis more concrete I want to give some examples of the research programmes of the Finnish Institute of Occupational Health on problems which belong to the different areas of Fig. 1.

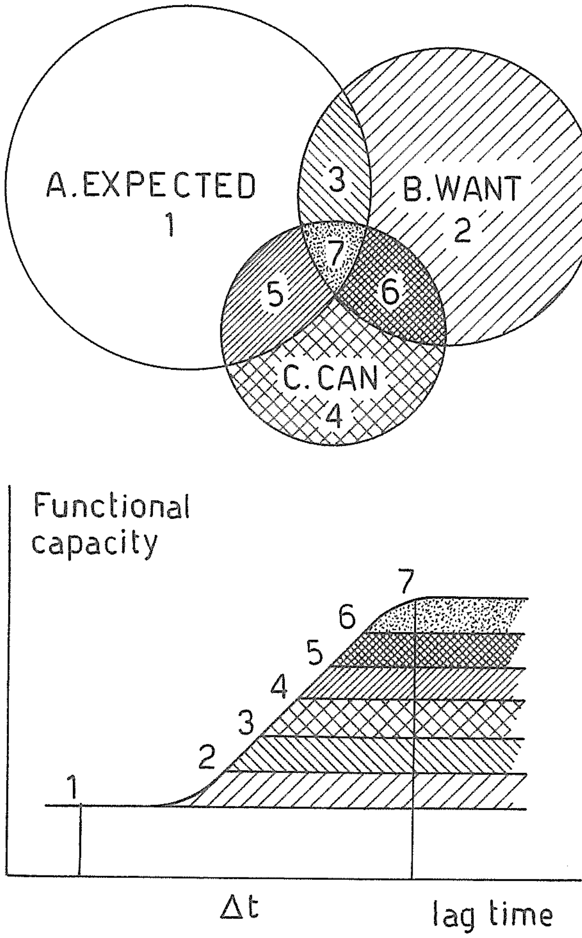

Fig. 1. – Operational capacity and areas of factors influencing the setting of priorities in the public health institution [1]

Example I – Prevention of vibration syndrome among Finnish lumberjacks

In the beginning of the 1970's the prevalence of white finger disease was 40%, and of symptoms like numbness in hands was 80% among the Finnish full–time lumberjacks.

The disease attracted the interest of the scientists of the Institute (area B) on the basis of their own interest (clinical observations), and on request of the trade unions and authorities (area A). The rough criteria for diagnosis had been developed, but particularly field methods for epidemiological studies of the outcome were lacking. Also, the main characteristics of vibration exposure, crucial for the development of the disease were not known. During the course of the project, a battery of clinical and anamnestic criteria describing the existence and the severity of the disease (TVD index) was developed, and an epidemiological follow–up study of the workers' was started [2]. Simultaneously the physical characteristics of vibration exposure were analysed. It was found that the average time of exposure to chain–saw vibration (prominent frequency 160 Hz) by lumberjacks was about 5,600 hrs, whereas, *e.g.*, the latency time for the onset of the disease by knife grinders (prominent frequency 1,000 Hz) was only 1,000 hrs. Cold, smoking, unprotected hands and poorly attenuated saws were found to facilitate the progress of the disease among the lumberjacks as well as the underlying non–occupational Raynaud–syndrome. On the basis of the above findings a number of preventive measures were recommended:

- vibration attenuated chain–saws;
- careful protection of hands with warm gloves;
- breaks in the work;
- warmed transportation and break cabins;
- noise protection;
- anti–smoking campaign;
- health examinations to find non–occupational Raynaud cases.

The recommendations were well accepted by workers and employees.

Ten years later the situation is the following: the prevalence of the disease (Fig. 2) in the same study group is about 7% and the degree of severity of the disease has been reduced remarkably (Fig. 3). This was a real success in the prevention of the disease which threatened the health of nearly half of our lumberjack population. Now the disease has been almost totally eliminated, as it is shown in the statistics on occupational diseases (Fig. 2) [3]. This was a project where we both wanted and were expected to do research but the development of our

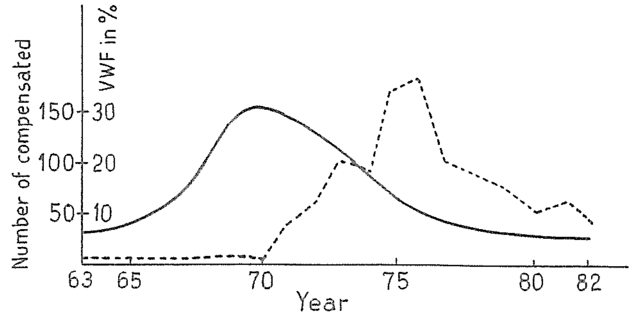

Fig. 2. – Prevalence of white finger disease among Finnish lumberjacks in 1963–82 (__) and number of vibration-induced vasospastic diseases in the national registry of occupational diseases in 1963–82 (_ _ _)

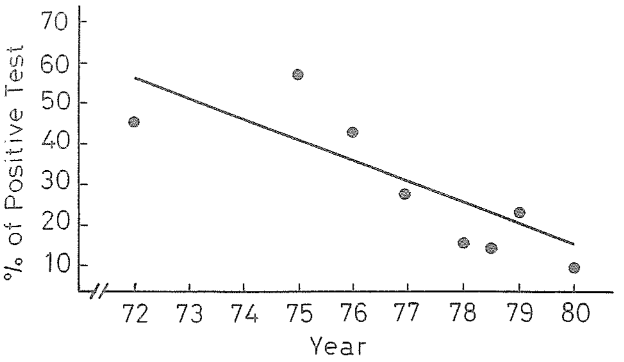

Fig. 3. – Degree of severity of the white finger disease in lumberjacks in 1972–80 measured as percentage of positive results in cold provocation test

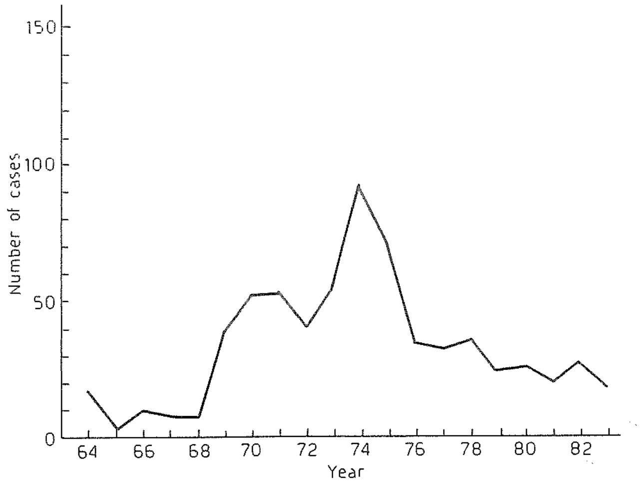

Fig. 4. – Number of lead–induced occupational disorders registered in the Finnish national register of occupational diseases 1964–82

methodological capacity and the effects of the preventive actions took about 5 years before the impact started to be visible.

Example II – Prevention of lead poisoning in industries

Based on their own clinical observations (area B), twenty years ago Dr. Hernberg and his co–workers started a programme for developing the criteria for lead exposure and research on early diagnosis of industrial workers. During the programme the blood lead concentration (BPb) was found to be the most practical indicator for lead exposure, whereas blood haemoglobin concentration (BHb), and urinary delta–amino laevulinic acid (U–D ALA), and blood zinc protoporphyrin were chosen for the indicators of early lead effects in the field studies. By using these indicators the occurrence of lead exposure was surveyed in Finland and the number of potentially exposed workers was found to be about 20,000 persons. Their companies, branches of industries and occupations were identified, and the levels of exposures were estimated [4]. A project for research on sensitive indicators of early clinical effects was started parallel to the field project. It was found that exposure to lead, as low as that producing BPb of 30 μg/dl, decreased conduction velocities of peripheral nerves, and in psychological tests worsened performance in visuomotor performance and visual intelligence were observed [5, 6].

On the basis of these findings the recommendations for exposure limits were given to the authorities, and practical guidance was addressed to (Table 1) occupational health physicians [7]. The impact of the programme can be seen at several levels. First, government has given a special governmental ordinance on the prevention of lead risks in work, second, the average blood lead levels of workers have decreased substantially during the programme. First the number of registered occupational diseases (Fig. 4) was increased because of the increased sensitivity of the diagnostic network, and thereafter it decreased

Table 1. – *Lead control in occupational health practice*

BPb	Occurence	Number of health examinations/year
< 40 μg/100 ml	All workers	None
≧ 40 μg/100 ml	In one worker	1 for all potentially exposed
≧ 60 μg/100 ml	In one worker	2–4 for all potentially exposed
≧ 70 μg/100 ml or clinical poisoning	In one worker	6 for all potentially exposed

as a result of preventive measures [8]. The methodology developed here was also used in the epidemiological research on the environmental lead exposure of urban vs. rural populations [9].

Example III – PCB accidents

In August 1982, the Institute was alarmed to help in a PCB accident after midnight in the middle of the summer vacation season. We were expected to give an urgent response without any own interest or capacity (area A, 1) when 20 capacitors containing 20 l of PCB each exploded in one of the largest paper mills in Europe. About 400 l of PCB were lost and 100 l were burned by electric arc. Fifteen persons were heavily exposed to PCB and its pyrosynthetic derivatives, and 150 persons were contaminated. Closing of the factory cost 1 milion US$ per day.

Without any earlier experience we had to take samples, analyse the PCBs, dibenzofuranes and possible dioxines, make risk assessmet and give re–entery limits for the plant. We also had to follow–up the decontamination (Fig. 5) as it was expected. All this could not be done during the first week. But within a month, sufficient functional capacity was reached, and later on it has been completed. The capacity is currently in full use. Since August 1982 we have had some 40 PCB fires, explosions or leaks (Table 2). At the same time advise was given to the government which decided to start a programme for the replacement of PCB containing electrical apparatus with PCB–free facilities by the year 1990. This implies that the problem of PCB fires and explosions will disappear, but then we will get a new problem of the contaminated scrap and of PCB wastes [10].

Example IV. – Prevention of diseases of upper extremities caused by strain in packaging work

An example on the Institute's attempt to respond to the problem caused by strain in repetitive work in a Packaging line is the development of preventive ergonomic programme in two factories. By the year 1975 the number of the acute injuries of the connective tissue, such as shoulder–neck syndrome, tendovaginitis, peritendinitis and epicondylitis increased in the plant very rapidly. Up to 80% prevalences were found among the women who worked in the assembly–line packing. Dr. Kuorinka and his co–workers made a health examination of exposed workers and found injuries in 70% of them. The control group of shop assistants had the prevalence of 37%. The exposures and the load of repetitive movements of workers were analyzed in detail [11]. On the basis of these observations the targets for the preventive actions were indicated (table 3). A preventive programme was implemented and the impact became visible in less than a year. The incidence of new cases remained at zero level for years (Fig. 6).

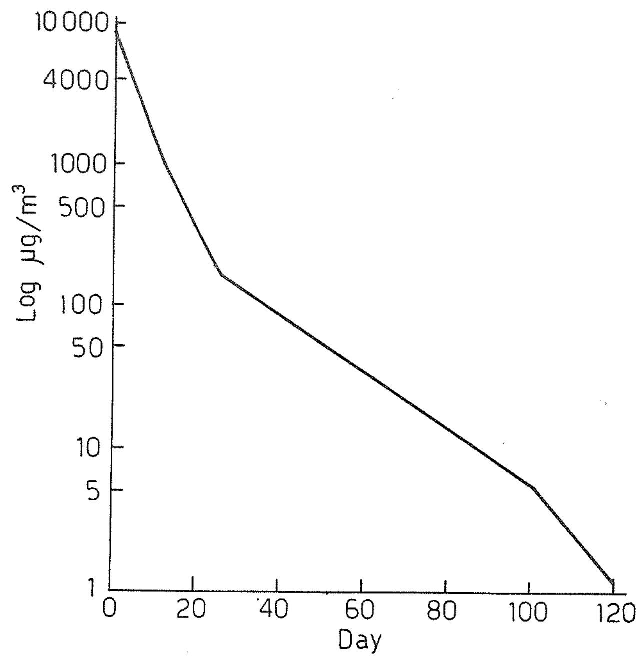

Fig. 5. – Decrease of PCB concentrations in the air of contaminated rooms of the paper mill during the course of decontamination

Table 2. – *Measured contaminations by PCBs and their derivatives in some PCB accidents in Finland*

Type of accident	N.	Lost PCB, l	PCB in air µg/m³	PCB on surfaces µg/m²	TCDF on surfaces µg/m²	2,3,7,8 TCDF on surfaces µg/m²	Number of persons exposed
Large explosion	2	300	16.000	50.000	25.900	3.850	152
Limited explosion	16	< 16	50	300	12.000	4.000	113
Large leak	1	10	1.900	33.000	3.300 *	—	?
Small leak	6	< 6	15	—	—	—	?
Ext. fire	2	?	—	110.000	< 10	< 10	open air
Electric fire	1	?	15	1.500	< 10	< 10	?
TOTAL	28	<332	—	—	—	—	>265

* Calculated on the basis that PCB in concern contained 0,01 % of PCDF and PCDD.

Table 3. – *Preventive ergonomic programme*

1. – Technical improvements of equipment
2. – Improvements of work environment
3. – New design of packing methods
4. – Extension of job rotation
5. – Emphasis of work instruction
6. – Ergonomic training
7. – Pause gymnastics
8. – Immediate health care

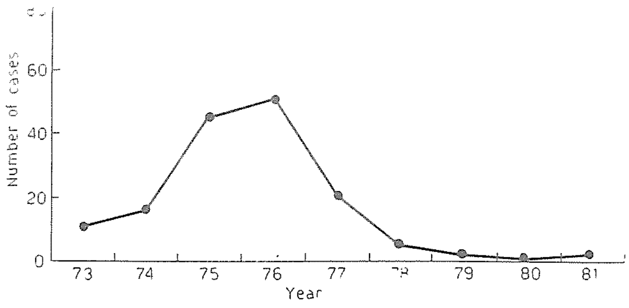

Fig. 6. – Impact of preventive ergonomic programme on occurence of acute connective tissue disorders of upper extremities caused by repetitive tasks in 1973–81

Unfortunately, the success has not been so good in the whole Finnish industry, because the number of these acute diseases in the register of occupational diseases is still increasing (Fig. 7). This is a typical example of an area where it was easy for the team to give a quick response (Area C 7).

Example V – Research on respiratory allergies

A programme for improved diagnosis of occupational asthmas and allergic alveolitis was started in the first half of the 1970's. It was based on clinical observations, and on the personal interest of an expert in the staff of the Institute (Area B). The programme included development of diagnostic criteria, establishment of modern battery of pulmonary function tests including facilities for human exposure chambers for provocation tests, survey of biological and other organic dusts in the working environment, and studies of allergenic components of plasts. Before the start of the programme the number of registered asthmas had been rather low; after starting the action the number of asthma cases increased quickly, and is still rather high. Several new causes of asthma such as di–isocyanates, phtalic acid anhydrides have been found. We have also learned a lot of the allergic alveolitis caused by molds in agriculture, and bacteria in air–conditioned working rooms. The methodology developed for the diagnosis of occupational allergies was also employed in the studies of environmental allergy caused by single cell protein dust leaking to the air of a city from a single cell protein factory [12, 13].

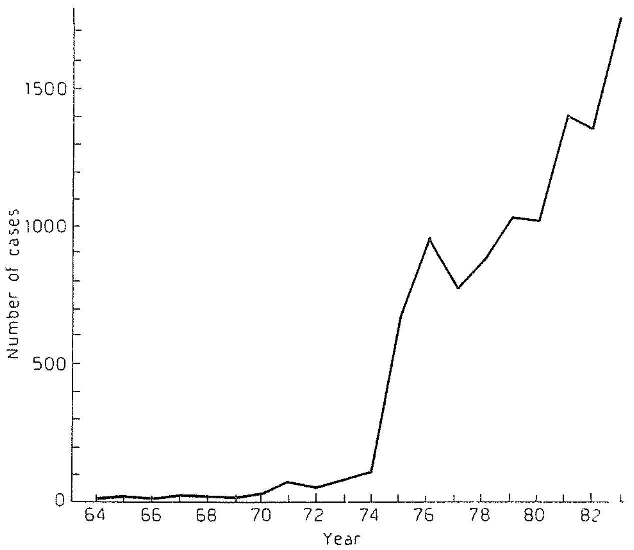

Fig. 7. – Number of registered occupational diseases of upper extremities caused by the repetitive task in 1964–82

To summarize

a) The initiative of action can be derived from several sources. The public health or scientific importance of the problem is not dependent on the initiator. The important problems may be identified outside or inside the scientific community but usually the balance of external and internal criteria is needed.

b) The latency time for the response of research can vary in wide ranges. This depends on what is the methodological and operational readiness of the research institution to solve the problem in concern. The functional capacity is a much stronger determinant of the delays than the motivation or the interest of the scientific comunity.

c) Clear public health and scientific results can be obtained with the help of scientific actions quite independently of what is the source of the initiative. An individual scientist starts a research which may have a remarkable public health impact. Vice versa an initiative from the public or interest groups and particularly from the decision–makers could lead not only to important public health advances but also to findings of a high scientific value.

d) The examples of a successful prevention in one area of the public health, *e.g.*, in the occupational health can radiate to the other sectors of health services and get even wider influence there. Thus, we need, for example, close connections between researchers and institutions of occupational health and those working in other areas of public health.

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