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THE RELATIONSHIP BETWEEN EXPOSURE MONITORING AND HEALTH STATUS IN THE OCCUPATIONAL SETTING. AN INFORMATION SYSTEM ON EXPOSURE LEVELS AND OCCUPATIONAL DISEASES

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Abstract. The relationship between the level of occupational exposure to different noxious factors and the health consequences of these in exposed populations is discussed using cadmium, lead, carbon disulphide and vinyl chloride as examples of occupational pollutants. The legal status and organizational system of monitoring the exposure to occupational pollutants and health effects in Poland are presented. The scope and sources of data on the occupational exposure level as well as the register of occupational diseases are evaluated.

INTRODUCTION:

Monitoring exposure to physical, chemical and biological factors is a commonly accepted practice allowing: 1. determination of the relationship between exposure magnitude to a given factor and health effects most often understood as accupational diseases; 2. evaluation of the effectiveness of technical, technological and organizational preventive measures; 3. assessment of health risk in a population exposed in a given working environment, on condition that sufficiently relible epidemiological, clinical and toxicological data allowing determination of the "dose-effect" and "dose-response" relationships are available.

Purposeful environmental and biological monitoring and drawing appropriate conclusions from the results obtained should, in consequence, lead to diminishing health risk. The relationship is particularly certain in the case of exposure to lead and cadmium. For both elements, the well evidenced data on critical organs and the "dose-response" relation-

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ship are available. They formed a basis for adopting recommended health-based concentrations in biological material and in the air. The recommended health-based biological limit (10) amounts to 400 μg Pb/dm³ of blood for males, and females over reproductive age.

In many countries, lead workers are removed from lead exposure when they reach a Pb "trigger level" (Table 1). In Finland this level

TABLE 1. International blood lead transfer limits (according to Winder and Gunningham, 1988)

Country	Medical Removal Level (μg/100 ml)	Comments
Austria	100	
Belgium	80	May be constrained by EEC directive 82/605
Canada (1976—1980)	70	
Denmark	60	
Eire (1976)	80	May be constrained by EEC directive 82/605
EEC (1986)	70	Some exceptions to 80 μg/100 ml
Finland (1985)	40	
France	80	
India (1948)	100	
Italy	70	
Japan (1072)	60	
Malaysia	73	Average of last three measurements is below 73 μg/100 ml
the Netherland (1986)	60	Some exceptions to 70 μg/100 ml; women — 45 μg/100 ml
New Zealand	80	
Norway	60	
Peru (1973)	60	Men only
South Africa (1979)	70	
Spain (1963)	80	May be constrained by EEC directive 82/605
Sweden (1983)	50	Three consecutive readings above 50 or one above 60 μg/100 ml
United Kingdom (1981)	70	Women — 40 μg/100 ml
United States (1983)	50	Average over last three readings or last six months
West Germany (1981)	70	Women — 45 μg/100 ml

is the same as the one recommended by WHO (13). In Sweden and the USA, workers are not allowed to return to work until the level of lead in their blood (Pb-B) has decreased to a "safe level" 400 μg/dm³). Due to the fact that lead caused, especially in the past, a great number of occupational poisonings in Poland, the Ministry of Health and Social Welfare issued special guidelines with regard to diagnosis of plumbism and its medical prevention. In this case, biological monitoring is closely related to registering plumbism incidence. The procedure adopted in this case is presented in Table 2. Application of these monitoring

TABLE 2. Biological monitoring of workers exposed to lead in Poland

Groups of workers	Action
1. Newly employed	Preliminary investigations: Pb-B, CP-U. Then Pb-B every month during 3—4 months.
2. Pb-B>500 μg/l	Pb-B, ALA-U, CP-U every 6 months
3. Pb-B 500—600 μg/l	Pb-B every 3 months; ALA-U, CP-U every 6 months
4. Pb-B 600—700 μg/l	Po-B, ALA-U, CP-U every two months
5. Pb-B 700 μg/l	Pb-B every month, ALA-U, CP-U every two months
6. Signs of increased absorption of lead	Removal with return to work at Pb-B of 600 μg/l

Pb-B — concentration of lead in blood
CP-U — concentration of coproporphyrins in urine
ALA-U — delta-aminolevuline acid concentration in urine.

programmes, together with other preventive measures, has led in practice in many countries e.g. Finland (4), to elimination of clinical lead poisoning. In Poland there are also no occupational lead poisonings reported at present.

In the chronic exposure, cadmium is cumulated in the kidney which is considered to be a critical organ. Tubular dysfunction manifested by increased excretion of low molecular proteins with urine is the first sign of functional changes. Normally, the level of cadmium in blood (Cd-B) is mainly an indicator of exposure over the last few months. A value of 10 μg Cd/dm^3 of the whole blood is proposed as the individual critical level if the exposure is regular and long-term. The level of cadmium in urine (Cd-U) can be used to estimate the body burden of cadmium. The individual Cd-U concentration should not be allowed to reach 10 μg Cd/g creatinine, since above this concentration there is a risk of renal dysfunction. Since the Cd-B and Cd-U levels mentioned above are the levels at which renal effects have been observed, and taking into account the long biological half-life of cadmium, it is recommended that control measures should be applied as soon as the individual concentrations of Cd-U and/or Cd-B exceed 5 μg Cd/g creatinine and 5 μg Cd/dm^3 of the whole blood, respectively. Consequently, these should be regarded as health-based biological limits.

The health-based recommended concentration of cadmium fumes or respirable dust in the air amounts to 10 μg/m^3 (10). It seems that, as in the case of lead, systematic application of monitoring programmes, together with some other preventive measures, has decreased concentrations of cadmium in the air (Table 3) and absorption of cadmium under industrial conditions. Even in workers employed in the most dangerous processes of production of pigments and alkaline batteries, the mean Cd-B levels approximate the health-based recommendation (Table 4). In

TABLE 3. Long-term data on cadmium concentrations in the air of work-rooms

No	Kind of production		Cadmium concentration in mg/m^3 in particular years					Reference
			1975	1976	1977	1980	1982	
1.	Cadmium alloys production (fumes)							(2)
		a)	1.5	0.11	0.2	0.12	0.035	
		b)	0.1	0.065	0.03	0.02	0.025	
			1964	1967	1969	1973	1979	
2.	Cadmium dyes production		0.6	0.6	0.11	0.06	0.06	(8)
			before 1950	1950—1954	1955—1959	1960—1964	1965—1979	
3.	Cadmium mill							(1)
	— agglomeration		1.0	0.6	0.6	0.6	0.6	
	— calcination		1.5	1.5	1.5	0.4	0.15	
	— smelting		0.8	0.1	0.1	0.1	0.04	
	— retorts		1.5	0.2	0.2	0.2	0.2	

TABLE 4. Contemporary data on Cd-B levels in workers employed at production and processing of cadmium

Process	Cadmium in blood (μg/l)	N	Reference
Cadmium mill	13.4 (2.4—44)	66	(7)
	14.7 (5.7—29)	28	
Alkaline battery factory	11.9 (5.4—23)	18	(6)
	7.9 (2.5—17)	10	
Alkaline battery factory	14.1±17	18	(3)
Glass bottle prod. plant	3.2 (2.4—4.3)	12	(11)
Cd plating dept. aero-engine fact.	4.4 (2.3—13.2)	6	(11)

the alkaline battery factory in Poland the mean Cd-B levels in groups of workers employed in assembly, chemistry and panel divisions have decreased since implementation of biological monitoring of exposure in 1983 from 18.40 and 49 μg/dm^3 (6) to 13.21 and 22 μg/dm^3 in 1989.

CS_2 belongs to a group of toxic substances with a long tradition of monitoring in the working environment. The beginnings of CS_2 monitoring in Poland date back to 1945-46. However, systematic monitoring was introduced in the years 1955-56 i.e. in the period when CS_2 concentrations were very high. It is to be noted that health effects found at that period seem to be the result of uncontrolled exposure to much higher concentrations in the years 1928-45. In the subsequent years the concentrations were gradually reduced (Table 5). Concurrent with the decrease of CS_2 concentration, chronic poisoning symptomatology has

TABLE 5. CS_2 concentrations in viscose cut fibers spinning mills in the years 1945—1980

Year	The range of mean concentrations mg/m^3
1945—1946	283—490
1964	77—140
1966	35—57
1978—1979	22—33

changed; the period of exposure preceding the occurrence of the first symptoms is longer. Improvement of the hygienic situation and alleviation of the clinical picture meant that more sensitive diagnostic methods for detection of chronic CS_2 poisoning were required. During the earlier period, neurological examinations (encephalopathy — 58.4%) were the basis for diagnosis. In the '80s, when CS_2 concentrations exhibited a further decrease to reach the value of the WHO health-based recommended exposure limit (10 mg/m^3), disturbances in the psychic sphere have been predominant in the clinical picture. They may be

TABLE 6. Clinical syndrome being a basis for chronic carbon disulphide poisoning diagnosis

Clinical syndrome	1968—1977 n=405	1980—1985 n=135
Encephalopathy (in neurological examination)	236 (58.4%)	38 (27.3%)
Psychoorganic or pseudoneurotic syndrome (in psychiatric and psychological examinations)	102 (24.7%)	76 (75.2%)

detected with sensitive psychological and electrophysiological tests after an exposure period exceeding 20 years (Table 6). This trend is concordant with that presented in the world literature.

The influence of environmental monitoring on biological effects of occupational exposure is also evident in the case of vinyl chloride. The introduction of a suspension method of vinyl chloride polymerization created an exposure to high concentrations in the working environment in Poland in the '60s. The six-year exposure induced the occurence of numerous chronic poisonings with this compound. Environmental monitoring and reducing the concentrations by 1-2 orders of magnitude have significantly improved the situation. At present, i.e. 15 years after monitoring introduction, no angio-vaso-osseous symptoms of chronic VC poisoning are noted, whereas the hepatic damages — which still occur — are found only in the workers who started their work 15-20 years ago when the VC concentrations were very high. So far no angiosarcoma cases have been found.

The above data point to the effectiveness of monitoring performed at local (factory, technological process etc.) level up to the point of full elimination of health effects. It is much more difficult to show such a relationship at provincial or country level, although many countries — through legal regulations — set up systems of monitoring occupational exposure to harmful agents and exposure-induced health effects. The causes of these difficulties are described below, based on Polish data.

According to The Labour Code, obligatory in Poland, the employer is responsible for occupational exposure monitoring in his working environment. The State Sanitary Inspectorate and the State Labour Inspectorate, which are responsible for checking that these duties are fulfilled by industrial plants, have been empowered by the Parliamentary bill — including the right to prohibit the technological process harmful to health and stop their production. In Poland there are currently over 700 laboratories usually located in or around big industrial plants. These laboratories monitor exposure in the working environment and measure pollution in the communal environment caused by the plants situated in their region. The plants which have not got their own laboratories avail themselves of the services provided, at their request, by the working conditions supervision institutions — chiefly by the State Sanitary Inspectorate but also by state-owned, cooperative and private institutions (laboratories). However, only the laboratories of the State Sanitary Inspectorate and some of the plant-connected laboratories are covered by an inter-laboratory quality assurance programme, which has been commissioned by the Chief Sanitary Inspector and initiated by the Nofer Institute of Occupational Medicine in Lodz.

In practice, only those factors in the working environment are determined, which according to the opinion of plant managers and supervision institution workers, create health risk. It is to be noted that the kind and prevalence of health impairments induced by a given factor occurring in the working environment constitute a significant socio-economic problem at least at plant level. Most frequently these are harmful agents specified in the list of maximum admissible concentrations (MAC) and intensities (MAI) published periodically by the Minister of Labour and Social Policy. Monitoring the exposure to chemical substances (e.g. benzo[a]pyrene, PAH) not included into the list of maximum admissible concentrations is rather exceptional. In order to unify exposure monitoring in the working environment, the Chief Sanitary Inspector issued in 1985 guidelines for performance of measurements of concentrations and intensities of noxious factors in the working environment and for evaluation of results.

Among the users of data on occupational exposure the following persons/institutions should be mentioned: A — at a local level: plant managers, occupational hygiene and safety departments, in-plant industrial health service, local units of trade unions, social labour inspector; B — at the voivodeship (regional) level: sanitary inspection, labour inspection, social labour inspection, Voivodeship Statistical Office; C — at the central level: the State Sanitary Inspectorate, the State Labour Inspectorate, the Ministry of Labour and Social Policy, Trade Unions.

At present, data on occupational exposure in Poland is chiefly available from two sources: a — annual statistical reports — prepared directly in the plants by occupational hygiene and safety services — now collected by voivodeship statistical offices, until 1983 they had been collected and analyzed by the Chief Statistical Office and the Ministry of Labour and Social Policy): b — annual reports of occupational hygiene departments at voivodeship sanitary and epidemiological stations collected and analyzed every three years by the Nofer Institute of Occupational Medicine in Lodz.

The data collected by voivodeship statistical offices allow to determine: the number of persons employed at the workposts creating health hazards i.e. those at which concentrations or intensity of harmful factors exceed permissible exposure limits in 10 groups of occupational hazards, and/or those at which work conditions fall into one hazard group associated with the work process; the number of persons with regard to whom occupational exposure was either reduced to the level determined by a hygienic standard or eliminated; the number of persons who were found to work in hazardous conditions in the year under review (Table 7). The obtained data, in the aggregated form, according

TABLE 7. The content of the form Z-10. Part 1. Elimination or reduction of hazard created by noxious for health factors related to work or working environment in which it is performed

Specification	Number of persons employed at workposts where exposure occurs				
	the state on Dec. 31 of the year preceding the report	with respect to whom the hazard was either eliminated or reduced		newly developed or newly found at the year under review	the state on Dec. 31 of the year under review
		Total	up to the level determined by standard		
noxious agents					
fibrogenic industrial dusts					
other industrial dusts					
noise					
vibration					
hot microclimate					
cold microclimate					
insufficient lighting at workposts					
other					
II. Hazardous factors related to work					

to the state ascertained on 31 December, 1986, have been presented in the Polish Statistical Yearbook edited in 1987 (Table 8).

Omitting the full analysis of data presented in Table 8 it is only certain that the information is too "rough" to make a more detailed evaluation of the hygienic situation on these grounds and to orient the policy of preventive measures properly. To this end, it is indispensable to obtain information on exposure to particular noxious factors and to stratify the groups of persons exposed into subgroups according to exposure magnitude.

TABLE 8. Workers employed under hazardous conditions in national economy (the state on December 31, 1986 according to the Statistical Yearbook of the Chief Statistical Office, 1987)

Specification	1980	1985	1986
	in thousand persons		
Total	1980	1473	1460
Hazards related to:			
working environment	1379	1109	1103
— effect of one group of factors	853	765	769
— two or more groups of factors	526	344	344
work:	511	364	357
— effect of one group of factors	370	291	290
— two or more groups of factors	141	73	67

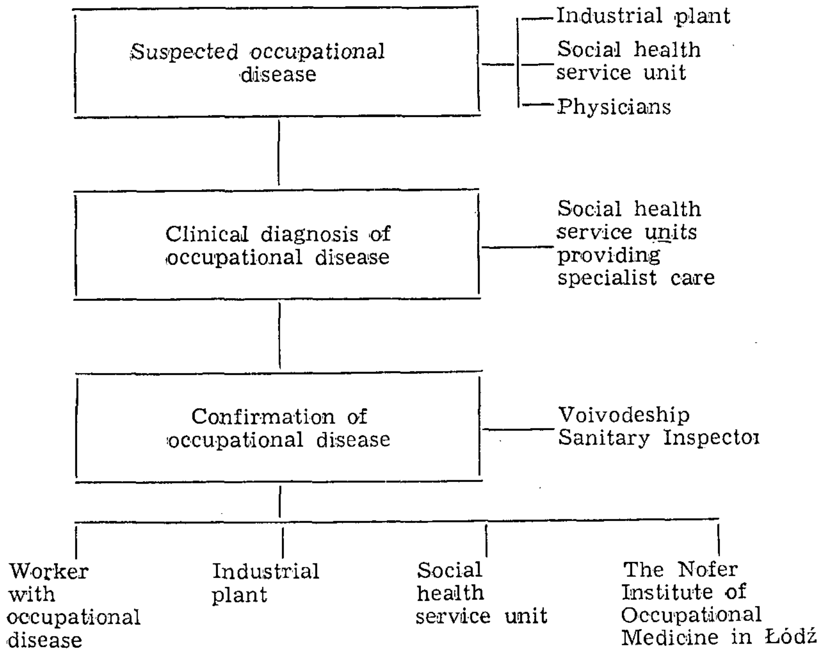
The State Sanitary Inspectorate had by 1966 initiated registration of information on occupational exposure in a unified form in the whole country. It should be stressed that workers on individual farms — about 4,400,000 — are not covered by supervision of the Inspection in respect of their working conditions. With regard to the remaining part of population working both in national and private sectors of economy, the State Sanitary Inspection has selected a group of about 70,000 plants in which noxious factors occur to the degree justifying their monitoring. In 1987, these plants employed about 7,500,000 persons. Each plant is liable to a periodical control check-ups during which measurements of working environment factors are performed and the State Sanitary Inspectorate collects appropriate documentation for the registration of information on occupational exposure. This system is based on the activity of two divisions of the State Sanitary Inspectorate: a — occupational hygiene, consisting of 49 units at voivodeship level and 327 field units; b — radiological protection, consisting of 49 voivodeship units.

Each of the divisions is concerned with surveillance of different groups of hazards and therefore they apply different methods in collecting and disseminating the information on occupational exposure. The information on exposure to a given chemical and physical factor comprises: a — number of persons exposed to a given factor at concentration/intensity ranging from 0.5 MAC or MAI to the 1 MAC or MAI value in various national economy branches; b — number of persons exposed to a given factor at concentration/intensity above MAC/MAI value in various national economy branches.

As data aggregation performed by the occupational hygiene units at the voivodeship and field levels limits the possibilites of using the system of information on occupational exposure, this year, the Nofer Institute of Occupational Medicine in Lodz has made an attempt to improve the existing system by obtaining more data directly from industrial enterprises. This will allow to combine the system of information on occupational exposure with the system of information on occupational diseases. Periodical medical examinations, the scope and frequency of which are determined in the guidelines of the Ministry of Health and Social Welfare of 1987, are another source of information on workers' health status. The relationship between exposure magnitude and its effects — occupational diseases — may be now analyzed only at the plant level, because only at that level there are a sufficient number of data to enable analysis. The analysis is performed jointly by industrial health care personnel and in-plant occupational hygiene and safety department workers and its results are used to develop the appropriate preventive action in the plant. At higher management levels, full analysis of the dependence between exposure magnitude and health effects (chiefly occupational diseases) is not feasible due to the shortage of appropriate minute data which is due to the data aggregation that has been made so far. The Nofer Institute of Occupational Medicine in Lodz has made numerous attempts to set up an information system of collecting and processing occupational disease data and some other health effect data which could be obtained directly from the plant. The newly developed system will operate in close collaboration with the institutions supervising working conditions and especially with the State Sanitary Inspectorate.

In 1970, the Polish Register of Occupational Diseases was founded at the Nofer Institute o Occupational Medicine in Lodz. This system — based on electronic calculation techniques — enables information to be obtained on all cases of occupational diseases ascertained in Poland in particular years. New legal regulations on the diseases, deemed to be occupational diseases, which came into force in 1983, have explicitely determined the principles of diagnosis, reportage, ascertainment and registration of the cases. The official form for reporting occupational diseases ascertainment — prepared at the Institute of Occupational Medicine in Lodz — has become mandatory. Thus a uniform system has been set up and the kind and scope of information on occupational diseases has been unified in the whole country (5). Brief characteristics of the system are presented in Table 9. At present the Register of Occupational Diseases at the Institute in Lodz contains over 133,000 cases. Each case of the ascertained occupational disease is recorded only once and comprises the following data: — ascertainment number, year of ascertainment, voivodeship, patient's forename and name, year of birth, address, workplace with its code number, national economy branch, sector to which the workplace belongs, location of the workplace, workpost,

TABLE 9. Scheme of ascertainment of occupational diseases in Poland



causal agents I, II, exposure level, duration of exposure, kind of disease, place of diagnosis. If necessary, it is possible to obtain the above information in various arrangements. This refers to all cases of occupational diseases ascertained in Poland.

The number of occupational diseases in Poland in the years 1984—1987 by nosologic units is presented in Table 10.

The impact of working conditions on workers' health status in general and on the development of work-related diseases is still an unsolved problem. It is expected that the introduction of uniform documentation of preventive examination — the project of which has already been prepared as well as the evaluation of working conditions covering not only the monitoring of exposure to physical, chemical and biological factors occuring in the working environment but also factors related to the kind of work and its organization — will allow more comprehensive information to be obtained.

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TABLE 10. Occupational diseases in Poland in the years 1984—1987, by nosologic units (5)

Occupational diseases	Number of occupational diseases				Number of occupational diseases per 100 000 employees			
	1984	1985	1986	1987	1984	1985	1986	1987
Total	8747	8626	9105	9845	72.2	70.3	73.2	78.3
Acute and chronic intoxications with chemical substances and their sequelae	623	495	472	465	5.1	4.0	3.8	3.7
Chronic diseases of bronchi induced by substances causing paroxysmal bronchospasm and pneumopathies with inflammatory proliferative reactions	124	139	157	144	1.0	1.1	1.3	1.1
Chronic bronchitis induced by toxic substances, irritant aerosols — in case of insufficiency of respiratory system	286	291	670	425	2.4	2.4	3.0	3.4
Pulmonary emphysema in glassblowers and musicians of brass bands — in case of pulmonary insufficiency	5	3	3	5	0.0	0.0	0.0	0.0
Chronic atrophic, hypertrophic and allergic inflammation of mucous membranes of nose, pharynx, larynx and trachea	221	209	155	188	1.8	1.7	1.2	1.5
Chronic diseases of vocal organ related to excessive voice effort	576	835	1067	1121	4.8	6.8	8.6	8.9
Diseases induced by ionizing radiation including malignant neoplasms	18	18	11	15	0.1	0.1	0.1	0.1
Malignant neoplasms induced by carcinogens present in working environment, except for those mentioned in point 8	20	31	42	65	0.2	0.3	0.3	0.5
Dermatoses	1103	950	837	890	9.1	7.7	6.7	7.1
Contagious and invasive diseases	1743	1709	1726	1929	14.4	13.9	13.9	15.3
Chronic diseases of locomotor system related to the way the job is performed	152	167	219	276	1.3	1.4	1.8	2.2
Chronic diseases of peripheral nervous system	19	36	54	75	0.2	0.3	0.4	0.6
Diseases of the eye induced by occupational chemical or physical factors	40	33	35	23	0.3	0.3	0.3	0.2
Noise induced hearing loss	1918	1993	2229	2350	15.8	16.2	17.9	18.7
Vibratory syndrome	616	619	550	544	5.1	5.0	4.4	4.3
Diseases induced by work in increased or decreased atmospheric pressure	1	—	—	—	0.0	—	—	—
Diseases induced by gravity load (accelerations)	—	—	—	—	—	—	—	—
Diseases of central nervous system, cardiac pace maker and conducting systems and gonads induced by electromagnetic fields	6	5	4	6	0.0	0.0	0.0	0.0
Heat hyperpyrexia syndrome and its sequelae	2	—	—	—	0.0	—	—	—

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