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O R G I N A L P A P E R S

THE IMPACT OF THE CHEMICAL INDUSTRY ON THE HUMAN ENVIRONMENT

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Key words: Chemical industry, Impact on environment and worker's health

Abstract. The magnitude of the emitted to the air dusts and gases, liquid and solid wastes disposal produced by chemical industry is presented. Impact of chemical industry on the environment is discussed. Some hazardous agents, occurring in the work environment, morbidity and sickness absenteeism rates, noted among employees in chemical industry, are considered.

According to estimates already published, the chemical industry could be located on the second place in dust emission after the power industry and on the third place after the power and metallurgical industries in gaseous emission (Fig. 1).

As far as water consumption is concerned, the chemical industry takes second place after the power industry and use 8.8% of total industrial water (Fig. 2a) Among chemical plants, the highest consumption of water is observed in fertilizers factories (17) (Fig. 2b).

As far as it concerns industrial waste water to be purified in Poland, the part discharged from chemical industry is the greatest, amounting to 22,1% of the bulk (17) (Fig.3). The great part of the waste water from the chemical industry (20.6%), despite its considerable chemical reactivity and biological activity is not purified any way (Fig. 3a). A major part of nonpurified waste water from chemical industry comes from the organic and inorganic industry plants and factories (Fig. 3b).

Accumulated solid wastes from the chemical industry classified as burdensome for the environment constitute 10.9% of their total quantity (17) (Fig. 4a) The main trades of chemical industries which discharge the greatest amounts of solid wastes are the following: fertilizers factories, inorganic industry and sulphur mining (Fig. 4b).

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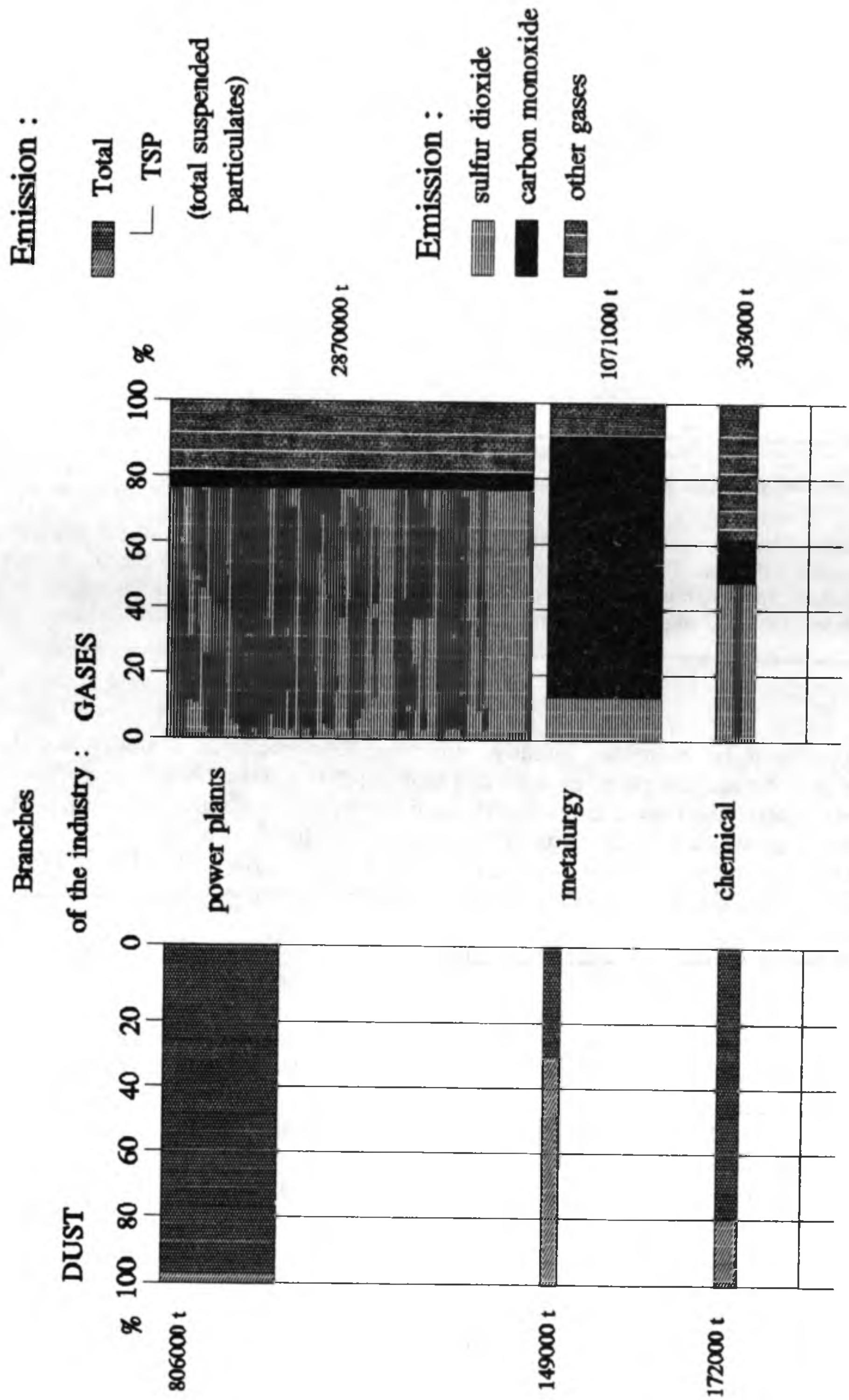


Fig. 1. Emission of industrial air contaminants in the industrial branches in Poland during 1989.

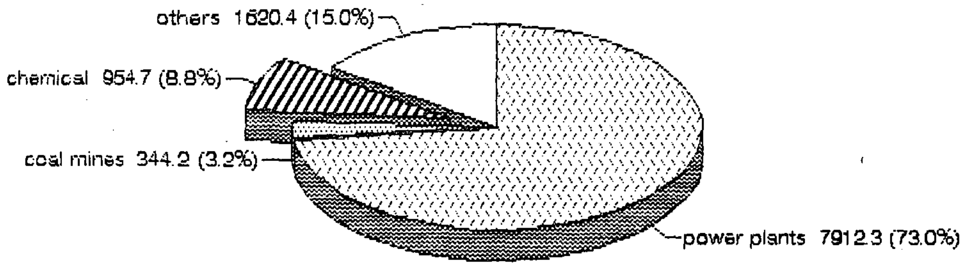


Fig. 2a. Water consumption by particular branches of the industry in hm^3 in Poland during 1989.

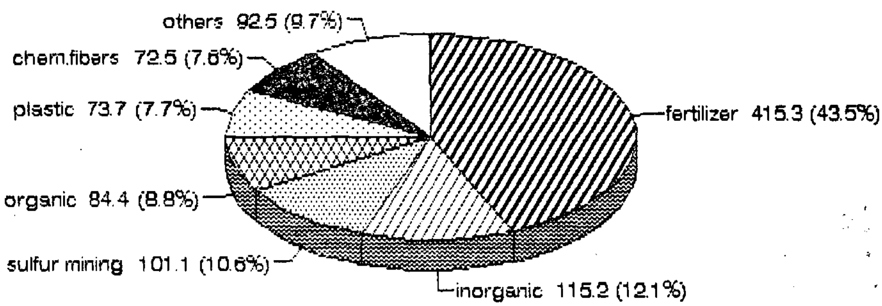


Fig. 2b. Water consumption by particular trades of the chemical industry in hm^3 in Poland during 1989.

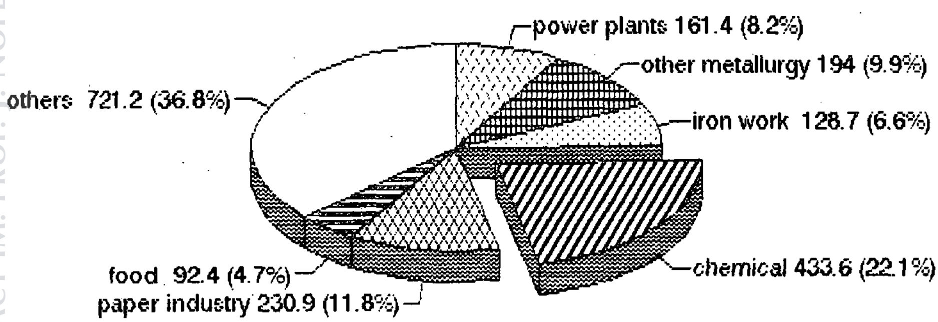


Fig. 3a. Total quantity of industrial sewage produced in particular branches of the industry in hm^3 in Poland during 1989.

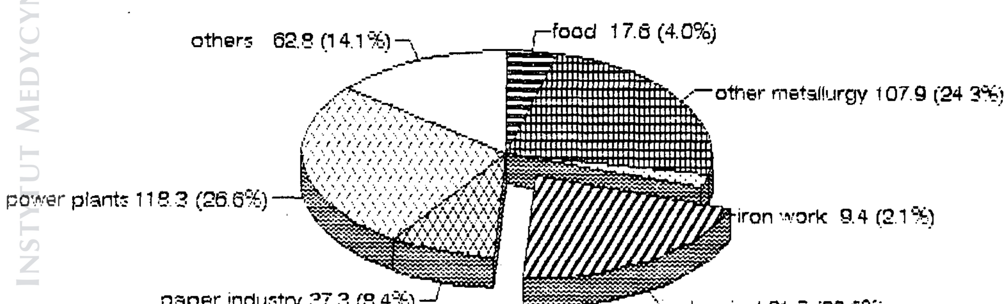


Fig. 3b. Quantity on unrefined sewage in particular branches of the industry in hm^3 in Poland during 1989.

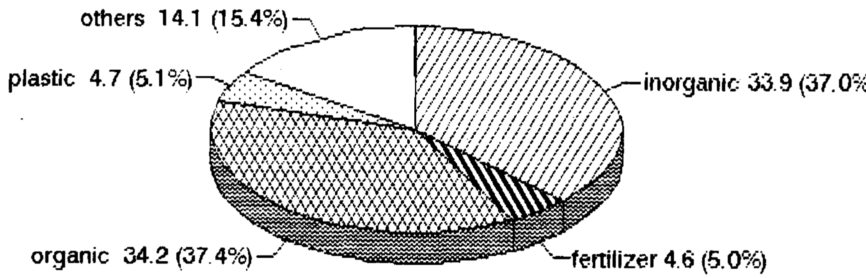


Fig. 3c Quantity of unrefined industrial sewage in particular trades of the chemical industry in hm^3 in Poland during 1989.

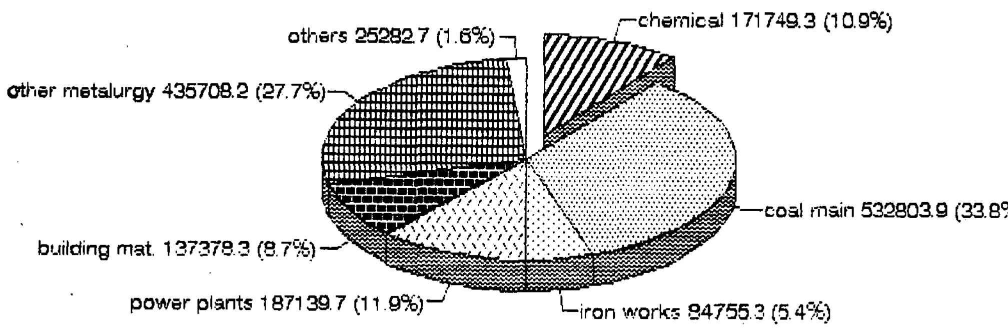


Fig. 4a. Total quantity of accumulated industrial solid wastes in particular branches of the industry in thousands of tons in Poland during 1989.

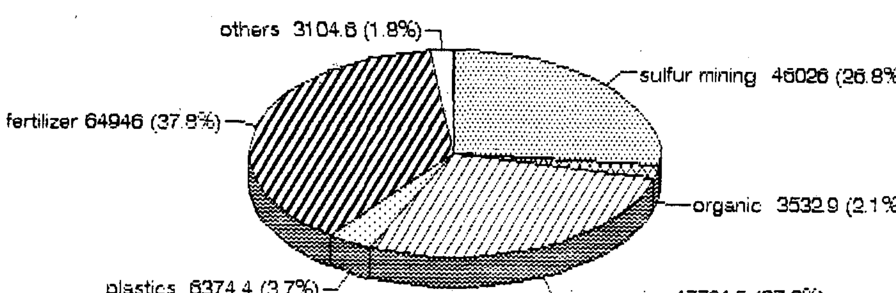


Fig. 4b. Quantity of accumulated industrial solid wastes in particular trades of the chemical industry in thousands of tons in Popland during 1989.

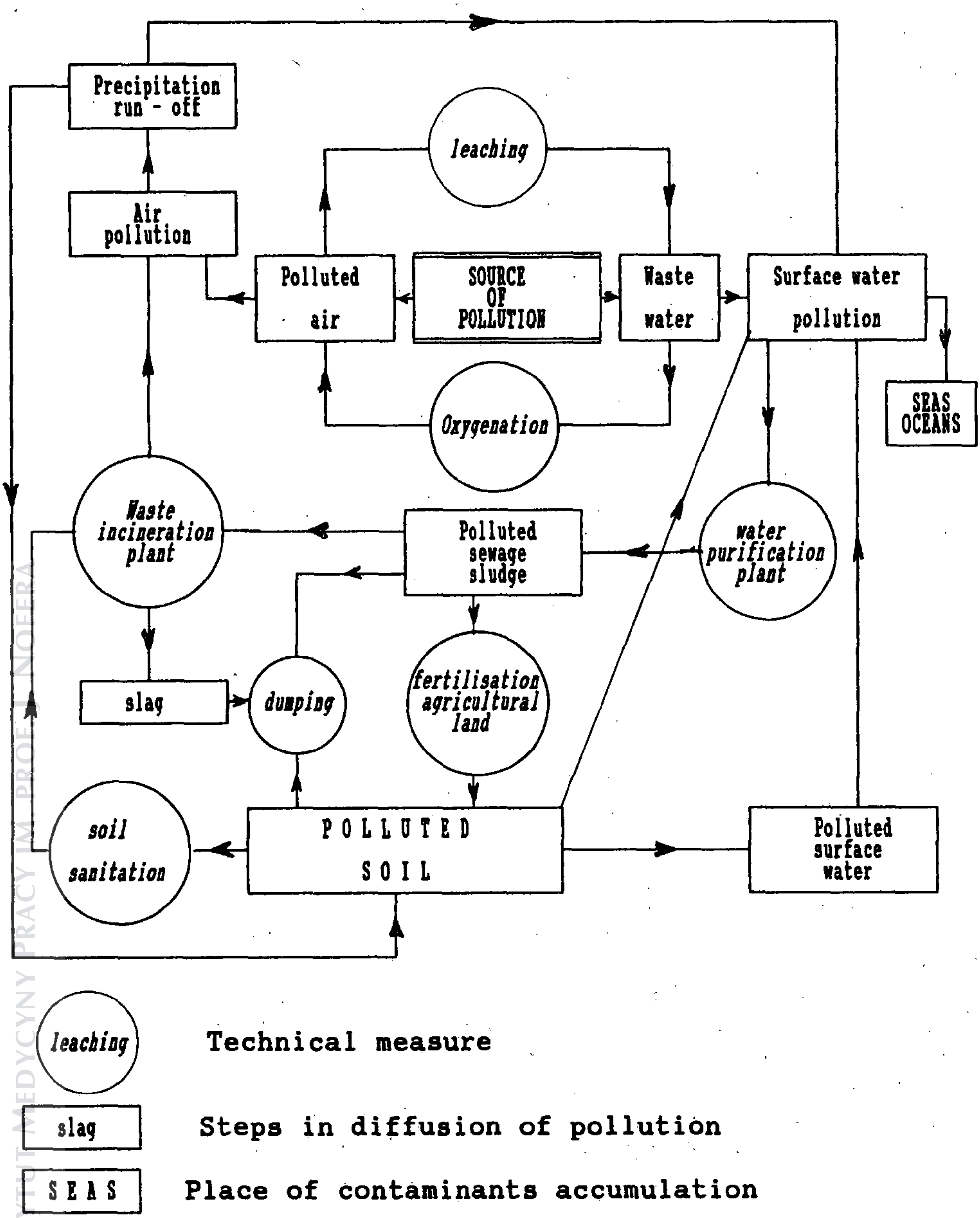


Fig. 5. Distribution and transport of chemical contaminants in the environment.

Apart from the hazards related to pollutants coming from the chemical industry, the human environment suffers badly from negative chemization related to the application of various chemicals in the agriculture, housing and food industries, transportation, etc. This fact is becoming increasingly apparent not only to scientists but also to public opinion.

Regardless of their primary sources the chemical contaminants, are distributed in the environment due to various, secondary physico-chemical and biological processes as shown in the diagram presented in Fig. 5 (11).

The energy flow between particular trophic levels, in the form of an organic matter results in the process of bioconcentration and biomagnification of toxic substances. Due to these processes a considerable accumulation of chemical contaminants is observed at the highest trophic levels of food chain. As an example could serve the bioaccumulation of DDT in the osprey (Pandion haliaetus) which is to 10^7 times higher in relation to the concentration of this substance in the biotype of this bird (21) (Fig. 6).

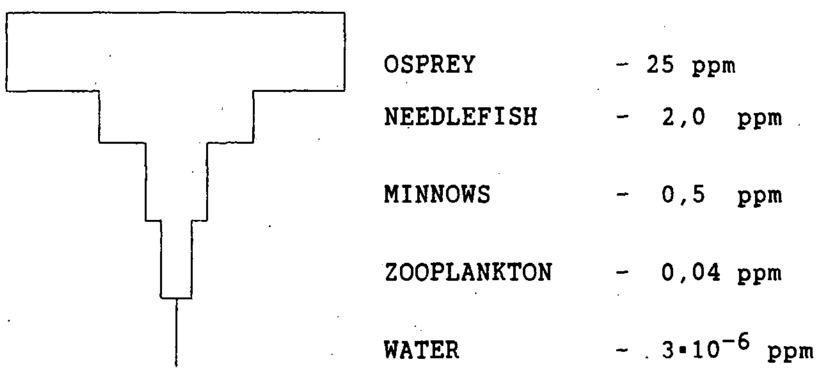
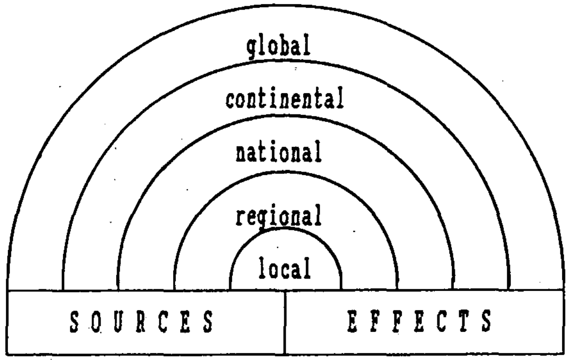


Fig. 6. Bioaccumulation of DDT in an estuary of the Eastern USA.

Generally taking the amount of chemical pollutant emissions released into the environment, their physio-chemical properties, the rate of chemical reactions and the distribution in the environment are responsible for various scale negative effects. (Fig. 7). Because of the time sequence of effects arising due to the environmental contamination, they could be identified independently of their character, as primary, secondary, tertiary and so on as presented in Fig. 8.

The receptors affected by hazardous substances coming from the chemical industry are: man, ecosystems, and the characteristic properties (morphological and functional) of the environment. In turn, the negative effects caused by the chemical industry on the above mentioned receptors can be assessed in terms of environmental health and/or economic indices. The latter can be estimated by measurable values (money) or by other conventional indices which correspond to the esthetic value of landscapes, plant and animal species threatened by extinction. The last two are difficult to quantify.

In this paper the following factors are taken into account: the degradation of required ideal living conditions for humans and ecosystems, and worsening



LEVEL	PLACE	PROCESSES
1. Local	houses, residential and occupational environment	interactions in the built up environment by litter, noise, nuisance, odour and emission from industrial installations in residential areas
2. Regional	landscapes	e.g. pedogenesis, erosion, eutrophication, waste disposal, dehydration, pollution from persistent cumulative air pollutants
3. National	river basins, coastal seas	water flows and balance e.g. pollution of the Gdańsk Gulf
4. Continental	continents and oceans	air currents, oceans currents – acidification of soil and lakes
5. Global	higher air layers	radiation and energy flows – climate change, deterioration of the ozone layer

Fig. 7. *Sources, effects and their processes at various scale of levels*

environmental properties as a negative effects of the chemical industry activities. Reversiblity of harmful effects and latency time should be taken into account.

For the illustration of this situation, the bioaccumulation of DDT and its metabolites which produces reproduction disorders in the peregrine falcon (13), the bioaccumulation of methylmercury in man resulting in Minamata disease in Japan (7) and eutrophication of natural waters due to the application mainly of phosphorous fertilizers in agriculture (12), may serve as good examples.

The tool used in proecological policy oriented towards the limitation or even elimination of harmful effects caused by the chemical industry is the technique of risk assessment.

The analysis of the environmental risk facilitates the forecasting of distribution and transformation of the substance in the environment, as well as identifying the type and intensity of effects hazardous to living organisms and environmental processes (3,12).

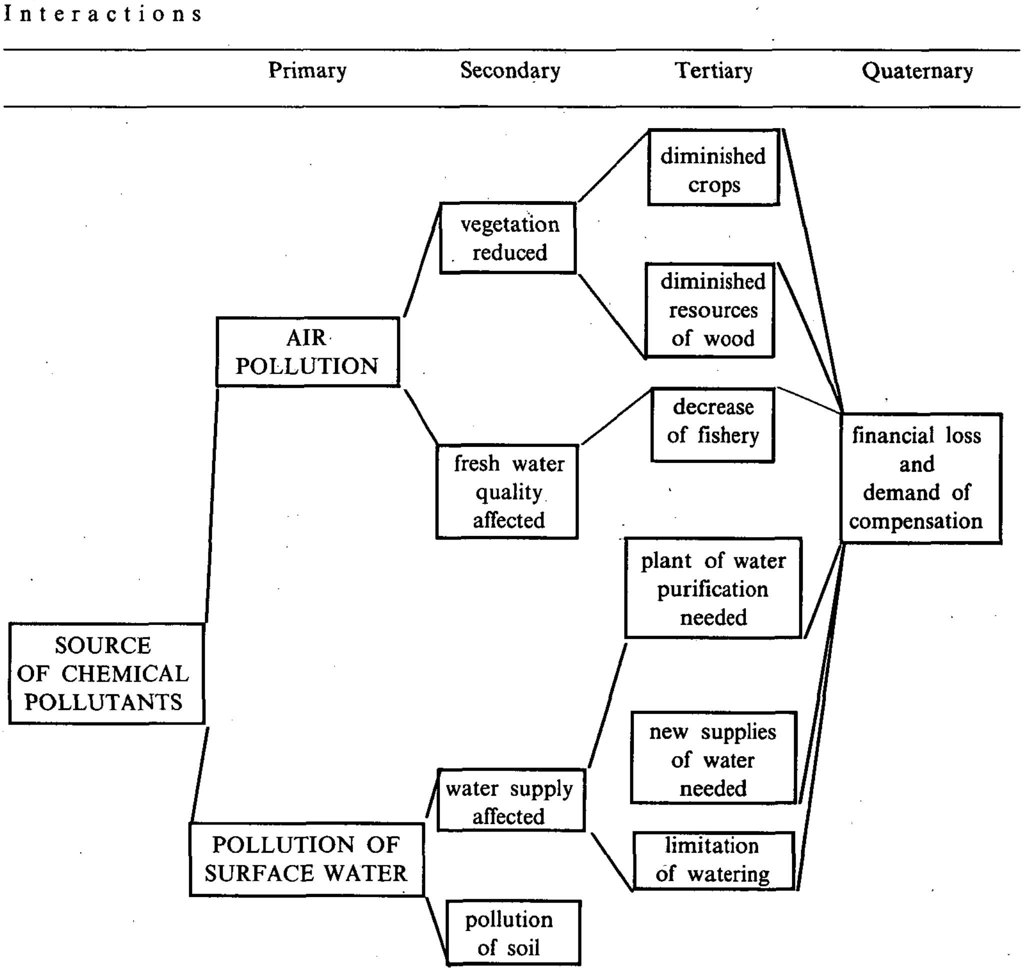
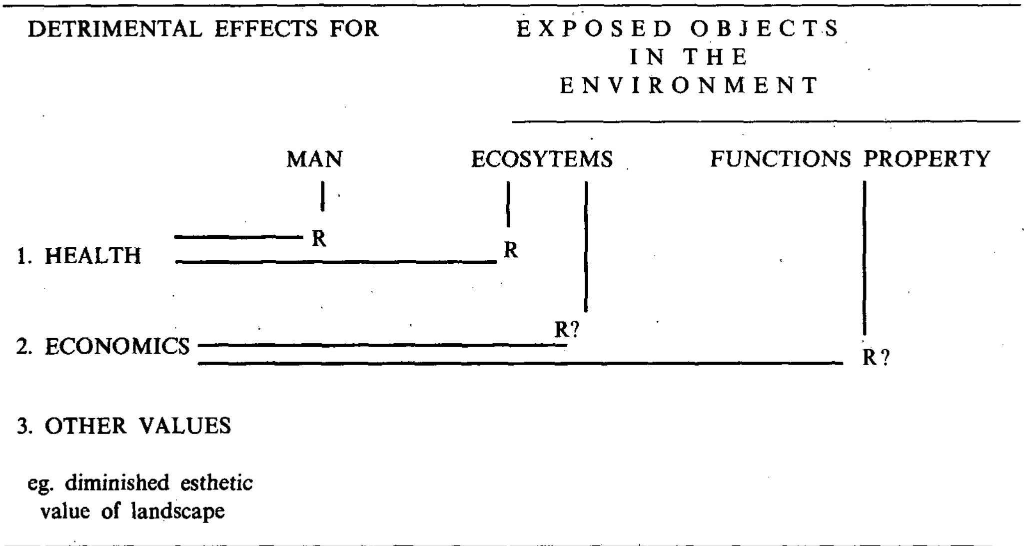


Fig. 8. Time sequelae of chemical pollutants in the environment.

This technique has become a basis for the estimation of both the highest and the lowest admissible risk limits. At the lowest limits, the magnitude of risk, in the meaning of the probability of the appearance of harmful effercts, is very small and practically insignificant. The estimation of border risk values, is carried out only for certain detrimental effects of the chemical industry observed in the objects exposed (Fig. 9). The question of the identification of risk limits understood in terms of the economy, and related to the impact of the chemical industry on ecosystems and the morphological and functional properties of the environment is still being discussed and analysed. The estimation of the risk limits with regard to human beings and biocenoses exposed to the detrimental impact of the chemical industry or, strictly speaking, to specific chemical substances, is the basis for setting up the hygienic standards which define their admissible concentrations in the various compartments and components of the environment. Taking the character of human



R — relationships for which risk limits are estimated.

Fig. 9. Combinations of determinal effects and objects to be protected for which risk limits can be established.

activity as a basis for stratification, one may identify four areas in the human environment with eventual differentiation of exposure to chemical substances related to:

1. the place of work — occupational exposure;
2. the municipal environment (outside dwellings and place of work) — so-called outdoor exposure;
3. premises within residential buildings — so-called indoor exposure;
4. leisure time, hobbies, etc. — so-called avocational exposure.

In order to characterise the impact of the chemical industry on the afore-said environmental areas, it is essential to answer the question of what criteria should be used as a basis for such estimation. According to the diagram presented in Fig. 9 there may be two measuring instruments related to health or economy. For justifiable reasons we have not attempted to analyse the impact of the chemical industry on the national economy but we intend to focus on its effect on human health which is considered as an integral quality index of the environment (15).

The work environment is the only area among those listed above where the impact of chemical industry can directly be estimated, namely the effect of existing working conditions on human health. In the remaining areas the secondary interaction of the chemical industry is most frequently observed as the chemical contamination of air, water and soil as well as the presence of chemical substance in food, building materials and elements of housing equipment. In those environmental areas human populations vary considerably, hence the population occupationally exposed in the chemical industry seems to be relatively homogeneous.

Assuming that the estimation of the impact of the chemical industry on the population employed is the easiest task to perform, further deliberations will be focussed on the health of this group as an integral quality index of the environment. An attempt should be made, first of all, to identify the factors present in this environment which may influence the health status of its working population and then to estimate the effect of those factors on selected health indicators.

In Poland, during 1988, about 40 thousand persons (15%) employed in the chemical industry were exposed to one harmful factor, at least (Table 1) (17). A considerable percentage (approx. 28%) of females in this group is a striking observation. This rate is higher when compared with the total percentage of females in the general population exposed in industry (20%) (Table 1). It is, however, difficult to identify the kind of chemical factor using only the published statistic data.

Table 1. Workers employed in hazardous conditions in some branches of the Polish industry.

Industrial branches	Total		One group of agents		Two and more groups of agents	
	together	only females	together	only females	together	only females
Total	979 063	182 285 (18.6%)	676 043 (69.0%)	152 562 (31%)	303 020 (9.9%)	29 723 (9.9%)
Total percentage of exposed females		100		83.7		16.3
Chemical industry	40 101	11 207 (27.9%)	34 152 (85.2%)	9 940 (29.1%)	5 949 (14.8%)	1 267 (21.3%)
Percentage of the total number of exposed females employed in chemical industry		100		88.7		11.3
Percentage of total number of exposed females in industry		6.15		6.51		4.3

According to the report prepared by the Division of Labour Hygiene of the State Sanitary Inspectorate (SSI) (14), out of 6,334 working posts under observation in the chemical industry, 30% of them proved to exceed MAC and MAS values. This, rate was similar to the average in industry as a whole (30.4%) (14). In view of these data, the number of chemical factor determinations performed in the chemical industry was equal to 42.8% of the total number of determinations of harmful factors in this industry at a mean value in industry as a whole, equal to 35.3% (14).

Among more significant harmful factors which occur in the chemical industry work posts the percentage of analyses performed is as follows: microclimate – 20.8%; noise – 14.5%; and vibration – 17.6% (14). It is well known that these factors may also be responsible for the development of specific diseases. The aforesaid figures which show the percentage of analysed chemical factors in relation to the total number of analyses performed in the chemical industry point, first of all, to the presence of those factors. From the logical point of view this corresponds with expectations but, however, does not explicitly prove that they are specific only to the chemical industry. This is because a number of chemical factors occur also in other branches of the national economy and in some of them, eg. the engineering, building and transport industries, more analyses of chemical factors have been performed, counted both in absolute and relative numbers.

On the one hand, this observation confirms that there is a considerable occurrence of chemical hazards in the working environment; for example studies in American industry indicate that about 25% of workers are exposed to one or more chemical factors in a working place (10). On the other hand, experience shows that the existing technical facilities and personnel available in the institutions which carry out research also decides on the number and kind of analyses performed.

It is known that sick absenteeism (SA) has proved to be an imperfect tool of measurement of the health status of working population (1,18), nevertheless, the analysis of its structure and tendencies is used to identify those branches of industry whose working conditions most significantly threaten the health of their employees (19).

The results of such analyses performed in Poland during the years 1970—1987 in selected branches of industry indicate that in certain branches of industry, the mean SA coefficient is higher than a total coefficient for industry equal to 4.39% (19). SA coefficients in some of industries under study are as follows: iron and steel — 5.21%; metallurgical — 4.88%; textile — 4.83%; and chemical (excluding the rubber industry) — 4.63%.

Within the chemical industry the highest SA coefficient is observed in organic and artificial fibres plants — 5.04%; inorganic and fertilizers — 4.68%; and rubber products — 4.5% (19).

In the chemical industry a dynamic increase of sick absenteeism due to cardiovascular diseases (18% higher than average in industry) is cause for attention. During the years 1970—1987 its mean annual increase was equal to 8% while in industry as a whole, this increase reached only 4.8%. Hence, the second place of this group of diseases after respiratory diseases among the five main causes of sick absenteeism in the chemical industry. A similarly high SA rate due to diseases of the musculoskeletal system was noted — mean 14.2% per year, as well as a higher than average SA rate due to diseases of the digestive and respiratory systems. In the rubber industry, as separate from the chemical, the highest rates of SA due to diseases of the nervous system and sense organs (mainly neuroses and mental disorders), deserve mentioning (19).

Apart from these, diseases of the musculoskeletal system take the third place among the causes of absenteeism in the rubber industry (0.65 12% higher than average in the industry as a whole) (19).

The analysis of SA in industry shows that its rate and causes are strongly influenced by the conditions of the working environment responsible, to a great extent, for workers' health problems. However, with regard to the chemical industry the analysis did not permit the identification of the main factors responsible for the dynamics of sick absenteeism.

The analysis of structure and incidence of occupational diseases in workers employed in the Polish national economy in 1990 (Table 2) indicated that among 336 cases of occupational diseases registered among chemical industry workers, the highest rates referred to poisonings — 33.9%, diseases of the skin — 14.9%, and hearing impairment — 12.8%.

Table 2. Some occupational diseases in 1988 in selected branches and trades of the Polish industry.

Branches of the national economy	Occupational diseases total	Number of diseases per 100 000 employed	Occupational diseases 1	2	3	4	5
Total	9 326 females 3 892	77.4	378	152	211	76	813
Industry (total)	4 609	102.6	303	55	161	62	468
Chemical industry	336	104.4	114	10	29	20	50
Metallurgy of non-iron metals	191	317.1	95	0	1	0	6
Textile industry	367	109.8	1	14	8	0	15
Iron works	325	228.4	8	2	45	11	32

1. Acute and chronic poisonings and its sequelae.
2. Bronchopatics and diseases induced by substances involving paroxysmal spastic conditions and pneumonopathies with inflammatory reactions.
3. Chronic, atrophic, hypertrophic and allergic rhinitis, laryngitis, pharyngitis and tracheitis.
4. Malignant neoplasms induced by carcinogenic agents present in work environment (without ionizing agents).
5. Dermatosis.

It is worth noting that hearing impairment produced high rates of occupational diseases in other branches of industry eg. textiles – 82.0%, machine-building – 50.8%, coal mining – 48.2% (16).

Another important observation is that the rate of malignant neoplasms is highest in the chemical industry when compared with other branches of industry. Also, a considerably high rate of respiratory diseases in this group of workers should be noted (29 cases). Higher rates of atrophic, hypertrophic and allergic rhinitis, laryngitis, pharyngitis and tracheitis were noted only in workers employed in iron steel-works – 45 cases (16).

To sum up, one may draw the conclusion that the information published thus far cannot be considered as basis for an integral quantitative assessment of the impact of the chemical industry on human environment and health. It is due to lack of a data base comprising, among other things: the kinds and quantities of produced, imported, stored and used substances, as well as those emitted and transported to the environment in wastes and sewages; concentration values of the substances to which man is exposed to in various compartments of the environment; concentration levels of substance present in environmental components (water, air, soil, etc); the number of persons exposed and so forth.

A thorough and reliable medical examination is still essential in the identification of the health effects of chemical substances. In the case of carcinogens their carcinogenic effect on human health was, in the first instance, disclosed due to observations made by clinicians and pathologists (4, 6, 9) and not due to broad epidemiological studies. The results of thorough medical observations together with information about the occupation performed, elaborated according to the scheme of Hoar et al. or the job exposure matrix (JEM) (2,8) facilitate in depth an analysis of the impact of working conditions on human health in the chemical industry.

A list of so-called environmental poisonings has been already proposed (5). A similar list of the most significant chemical hazards present in various areas of human environment (dwellings, working environment) or in various elements of the environment (water, air, soil, food, etc.) should be also set up.

Together with the findings of reliable monitoring, the list of those substances will create the basis for identifying the main sources of emission of chemical hazards, including those produced by the chemical industry.

In turn, studies of representative population groups by means of individual dosimetry would allow estimation of the magnitude of real human exposure and its sources. Then, it would be possible to conduct a quantitative analysis of health risks in persons exposed in various environmental areas (working environment, municipal environment, etc.) and to direct proper prevention.

This sort of strategy can, for example, be justified by the results of studies on the sources of the emission and human exposure to benzene. Vehicle traffic accounts for 82% of the benzene emitted, industry 14% and cigarette-smoking an apparently insignificant 1%: when we look at the human uptake percentages, the figures are rather different, in fact inverse. Cigarette-smoking account for the majority of uptake – 39% while vehicles and industry, at only 18% and 9%, respectively, are in a lesser position.

In the course of these studies it was estimated that the lowering of the rate of benzene from all stationary sources by 50% would decrease the magnitude of human exposure only by 2%, while such a result could also be achieved by a several per cent decrease of the average level of benzene in cigarettes (20).

Finally, in order to perform a comprehensive quantitative analysis of the impact of the chemical industry on the health of the population employed in this industry and on the general population, the following information handling is indispensable:

1. register of substances produced, used, stored and emitted into environment by the chemical industry;
2. list of the most significant chemical hazards present in various areas of the human environment (working and municipal environments, dwellings, etc.);
3. monitoring of the external environment and biological monitoring of the exposure; and
4. screening of representative population groups, employed in the chemical industry and sampled from the general population.

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