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BACKGROUND ON THE SYSTEM OF INTEGRAL EVALUATION OF HUMAN EXPOSURE TO TOXIC SUBSTANCES IN THE WORK AND MUNICIPAL ENVIRONMENTS

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Abstract. Exposure to toxic chemicals in the work, natural and home environments is recognised as combined exposure. The system of integral evaluation of human exposure should take account of all toxic substances occurring in all environmental media (air, water, soil and food), and all routes through which they enter the human body. To provide the integral evaluation it is necessary to develop different exposure scenarios based on dose intake or derived values. Following the toxicological criteria, calculated exposure indicators, after their standardisation and aggregation, should be converted into combined exposure indices. The index value will reflect the level of combined exposure.

INTRODUCTION

A growing number of new chemicals produced and coming in the market with widespread use in various sectors of society constantly contributes to their increasing occurrence in the work and living environments (20), as well as to the environmental pollution, inducing adverse effects as a result of industrialisation and chemicalisation of agriculture (4,32). All these lead to the increased exposure to harmful effects of toxic substances and may consequently pose potential hazards to human health.

The increase in environmental and health hazards does not go together with satisfactory improvements in methods for exposure and health risk assessments. The methodological insufficiency is observed particularly in the evaluation of combined exposure resulting from simultaneous absorption of many chemical compounds that occur in the natural, work and home environments. The interaction between harmful chemical, physical, biological, psychological and social factors has not been often taken into account when evaluating the exposure of populations or individuals (5,8).

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Methods for the evaluation of exposure to harmful chemical factors take rarely account of the interaction among numerous toxic substances, and pathways for exposure are traced only in unique cases (2,21).

In current legislation, hygiene standards that should constitute the basis for assessing health hazards are usually published in the form of a list of maximum allowable concentrations of particular toxic substances, and in a few instances only, it is recommended to consider their interaction with other toxins or other routes of their absorption by the human body. None of the legal regulations binding in Poland recommends to combine environmental and industrial hazards in the exposure evaluation (24,34–40).

The aforesaid comments indicate that in Poland the evaluation of human exposure to chemical factors, hazardous to human health, does not comply with the existing body of knowledge. Not all sources of exposure or pathways for absorbing various toxins are considered. Consequently, the lack of these considerations leads to incomplete evaluation that may provide misleading data on real, potential hazards to human health.

In countries of the European Union (EU), control of existing chemicals is ensured through the legislation based on risk assessment in respect to the application of various chemicals (33), and the guidelines of the World Health Organisation (WHO) published in co-operation with the International Labour Organisation (ILO) (1).

In WHO guidelines the results of the studies of acute and chronic exposure and all potential health effects, taking into account all possible pathways for absorption and routes of administration, provide the basis for setting standards for allowable concentrations of chemicals in the ambient and indoor air, food, drinking-water, soil and articles of daily use.

The obtained dose value diminished by the so called 'uncertainty coefficient' resulting from incomplete data becomes the basis for setting tolerance intake (TI). According to the guidelines (1), allowable TI means "...the amount of a constituent that does not result in any significant risk to human health over a lifetime intake... and its value may be expressed in different units depending on exposure routes for which it is determined... The dose value is usually calculated for a period of one week or one day".

In respect to inhalation exposure, TI value is expressed in μg or mg/m^3 of air concentration. The value of tolerable intake does not need to correspond with the value of absorbed dose that depends on retention or absorption capacity. Nevertheless it is close to reference dose (Rfd), reference concentration (RfC) and acceptable daily intake (ADI), recommended in risk assessment (27).

Tolerable intake can be used in determining the quantitative indicator for combined exposure to chemicals present in air, food and drinking-water, providing the basis for setting maximum allowable concentrations in individual environments. This approach ensures that the essential aim of human health protection is accomplished, taking into account the magnitude of total exposure to a given chemical occurring in air, water, soil, food and other environmental media. The hygiene standards should be developed for different scenarios concerning a 'reference' human being (15). Such scenarios will be representative of national, regional and local conditions of exposure.

It is obvious that accurate determination of indicator values depends on the significance and reliability of available toxicological data. Specific sources of uncertainty may cause that the obtained indicator values becomes the best actual estimations based on the most up-to-date data. Therefore, it is important that the guidelines for setting indicator values include clearly defined kinds and sources of uncertainty, as well as the aspects of their consideration in setting indicator values. Similar rules should be followed when elaborating the system of combined exposure evaluation.

Evaluation and limitation of hazards posed by existing chemicals should involve the estimation of real or potential hazards to human health and environment, as well as the assessment of unfavourable health effects. The evaluation is usually based on the intake dose of toxic substances and the occurrence of adverse health effects. It is also related to exposure at work and at home. This process embraces the determination of the toxic dose intake that induces specific health effect and the characteristics of hazards responsible for potential occurrence of specific health effect in the population under study. However, the establishment of such a system requires a large number of data derived from monitoring in order to estimate individual exposure doses of numerous toxic substances at workplaces and in the home environment. In Poland, like in a number of other countries monitoring of environmental hazards is not developed well enough to provide output data necessary to calculate doses of toxic substances. In view of inadequate monitoring data it is important to use all new available data in setting indicator values.

Exposure to toxic substances in the work and municipal environments is recognised as combined exposure. From the toxicological viewpoint it means that it is essential to take account of interaction between toxins to which people are exposed through an integral evaluation of exposure. Moreover, the integral evaluation provides the basis for better predicting of health risks resulting from the real magnitude of exposure or intake doses at existing exposure levels.

It should be stressed that the evaluation of combined exposure is one of more difficult problems faced by environmental and industrial toxicology. This problem has not as yet been successfully solved, although the researchers involved in these issues emphasise its significance and the need to make further attempts aimed at finding a suitable solution (9,26,42).

The first step towards the improvement of the present situation regarding the evaluation of exposure to harmful chemicals should involve an attempt to develop a system of integral evaluation of existing hazards, and comprehensive assessment of combined exposure through establishing data bases for all substances occurring in the human environment, their concentrations and potential harmful health effects in the population at specific concentrations and dose intakes.

IDENTIFICATION AND CLASSIFICATION OF HAZARDS

Numerous toxic substances occurring in the work and municipal environments differ in their effects on the living organisms. There are also different routes of exposure: by inhalation, by ingestion and through the skin. Therefore, developing the system of integral evaluation these aspects should be taken into consideration, and the formulation of its objectives should ensure the most comprehensive assessment of exposure.

In order to be able to carry out integral evaluation of exposure to toxic substances with different forms and intensity of effects it is important to select such exposure indicators that could be aggregated into one synthetic measure. Such synthetic measure should yield numerical values indicating the magnitude of the total exposure. The aggregation of indicators is backed up by the fact that all adverse health effects associated with the intake of toxins that affect the same living organism in many different ways may lead to diversified toxic responses.

All chemicals absorbed by the human body during the exposure process may be classified into the three major categories:

(1) chemicals with irritating effects: adverse health effects induced by them depend mainly on short-term exposures and do not cumulate during repeated exposures;

(2) chemicals with systemic effects targeted at individual tissues, organs or systems; and

(3) chemicals with carcinogenic, mutagenic and genotoxic effects.

These essentially differentiated groups of harmful effects, induced by the three categories of chemicals listed above, prompt the researchers to consider the possibility of using three partial measures that allow to provide characteristics and quantitative analysis of combined exposure. This approach is presented in Fig. 1. As depicted by the diagram, for substances with carcinogenic and systemic effects, the dose of individual substances absorbed through all possible routes for each kind of exposure should be first defined. The dose values should be expressed in units used in risk assessment (mg/kg b.w. per day^{-1}) (27,28,29). In respect of chemicals with irritating effect the concentration of past exposure should be calculated and expressed in mg/m^3. Then, the defined doses or concentrations should be referred to existing limit levels determined by mechanisms of activity. Unit risk (UR) or carcinogenic slope factor (SF) constitutes such limit levels for carcinogenic substances; reference dose (RfD) or acceptable daily intake (ADI) for substances with systemic effect; and reference concentration (RfC) for irritating substances (27,28).

Doses or concentrations divided by relevant admissible limit levels should yield values of exposure indicators for each substance. Standardised and aggregated exposure indicators for individual categories of chemicals determined by mechanisms of activity provide the basis for estimating indices of combined exposure. Their values help to distinguish exposure levels responsible for health effects from exposure levels that do not result in any significant risk to human health.

EXPOSURE SOURCES AND ROUTES OF TOXIC SUBSTANCE INTAKE

In the work environment as well as in the municipal environment there are usually the same sources of toxic substances (air, water, soil and food). The extent of hazards depends on toxic substance concentrations that occur in the environmental media listed above. Whereas the magnitude of exposure is related to doses of toxins absorbed by the human body through all possible routes.

Scenarios of exposure in the work and municipal environments differ, therefore, the system of its integral evaluation should be comprehensive enough to ensure its feasibility and functioning in every possible pattern of exposure.

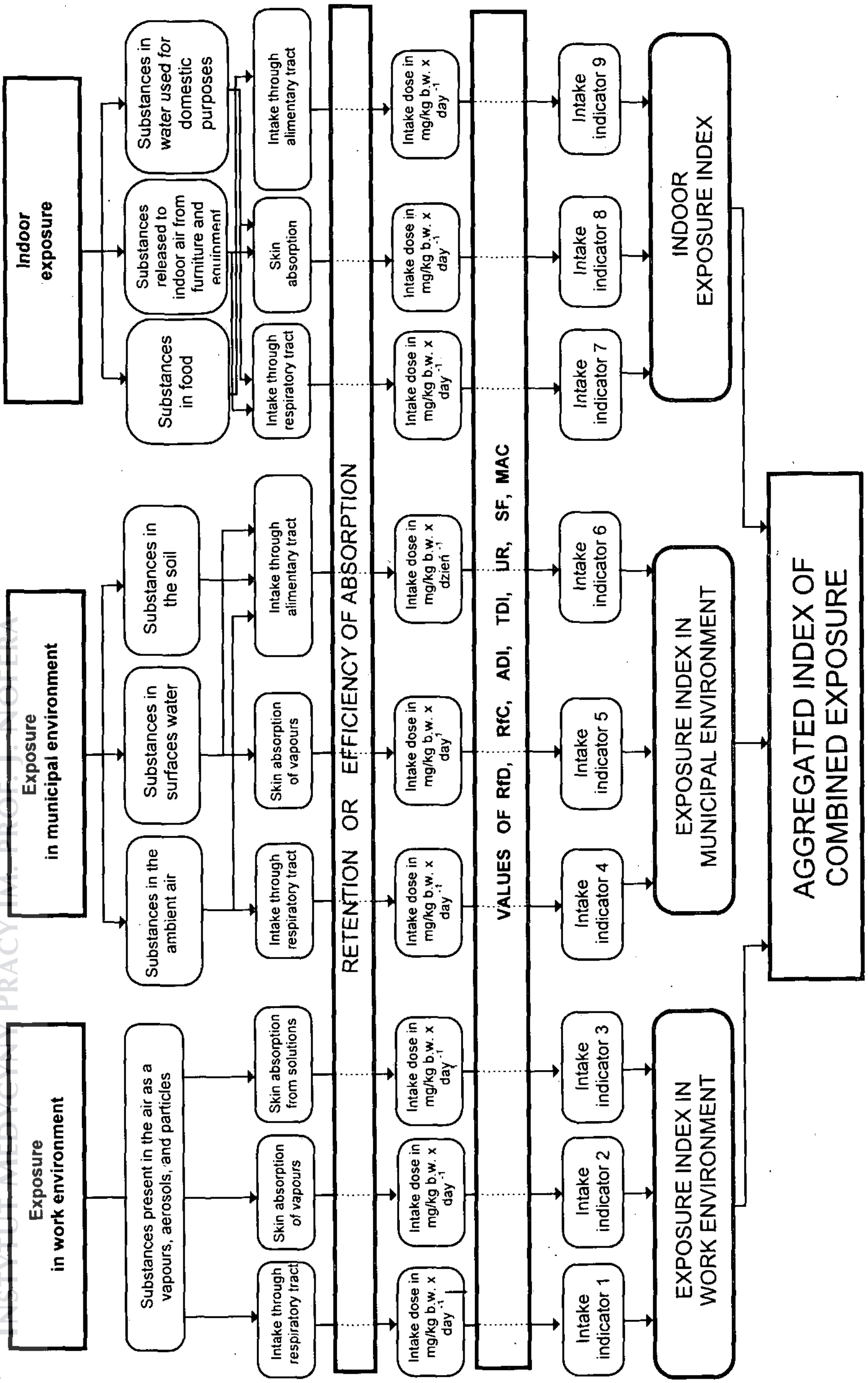

Fig. 1. The scheme of combined exposure to the specific toxic substance.

Acquisition and availability of data on toxic substance sources is essential in estimating intake doses of toxic substances. Owing to well developed monitoring, relatively large number of data is available on toxic substance concentrations in the air of the work, municipal, and home environments. For these environments hygiene standards have also been laid down in the form of legal regulations setting the maximum allowable concentrations of toxic compounds (34). These standards can be partly used as the guideline criteria for defining allowable and safe levels of human exposure. Unfortunately, there is much variation in the values of allowable concentrations of toxic substances in the work and municipal environments. That results not only from different periods of time of toxic substance activity in those two environments and differentiated sensitivity of persons exposed, but also from different objectives taken into account when setting maximum allowable concentrations. Table 1 presents some values of maximum allowable concentrations for the municipal (34), home (35) and work environments (2). The most pronounced differences in guideline values are found between the work and municipal environments. Despite the fact that maximum allowable concentrations in the air of the production premises are based on doses collected during a 40-hour working week at a 40-year duration of employment, the differences in values of both groups of guideline values are not justified by the population health risk (25,29).

Table 1. Maximum allowable concentrations of a group of toxic substances in ambient air (35), indoor air (36) and air of the work environment (34)

The toxic substance	Maximum allowable concentrations for various environments (in $\mu g/m^3$)		
	Ambient air — averaging time 24 h	Indoor air in premises of categories A and B[a]	Air in the work environment
Sulfur dioxide	150	not established	2 000
Nitrogen oxide	150	not established	5 000[b]
Formaldehyde	20	50–100	500
Particulate matters	120	not established	300–6 000
Carbon oxide	5 000	3 000–10 000	30 000
Mercury — vapours	0,3[c]	1–3	25
Phenol	10	20–50	10 000
Benzene	10	10–20	10 000
Xylene	100	100–150	100 000
Vinyl chloride	5	5–10	5 000

[a] Category A — residential premises, permanent premises for sick people, or children and young people, premises for storage of food products, Category B — premises in buildings for public use, and accessory rooms in homes,
[b] as nitrogen oxides,
[c] total in gaseous form and in particulate matter.

In view of the above, uniform criteria for the evaluation of hazards associated with the absorption of toxic substances, should be applied for the aggregation of exposures resulting from pollution of air in the work, municipal and home environments.

Food and water constitute other sources of toxic substances that are absorbed by the alimentary tract. Toxic compounds may permeate to food products from pollutants present in soil or occurring during the production processes. Drinking-water may also be polluted due to contamination of surface water and groundwater supplies, and chemicals used in the process of water treatment before it is supplied as drinking-water. Monitoring of water and food contamination with toxins is still inadequate in Poland. Therefore, the assessment of toxic substance intake with water and food can be only based on general data on the nutrition habits and daily diets (3,6,7,10–14,16,17,19,22,23,30,31,41) taking into account harmful substances contained in foodstuffs and drinking-water (3,13,23,30,41). It is important to apply also in this regard uniform criteria for evaluating harmful effects of substance intake.

In the conditions where toxic substances, occurring in the form of vapours, mists, aerosols, solutions or liquids, permeate the skin, the extent of existing exposure should be assessed and taken into account in the hazard aggregation.

SELECTION OF PARAMETERS AND PROCEDURES FOR INTEGRAL EVALUATION OF COMBINED EXPOSURE

In integral evaluation of combined exposure it is important to take account of all parameters affecting its magnitude. The sufficient data are not always available, if that is the case, derived values should be researched for, or extrapolation/interpolation of existing values should be applied. The integral evaluation comprises three steps:

Step 1 involves the identification of human exposure routes in the differentiated industrial, outdoor and home environments. To this end, it is necessary to identify toxic substances occurring in all environmental media: air, water, soil and food, as well as to define pathways of toxin absorption, and exposure duration separately for each environment under study.

Step 2 involves the estimation of absorbed doses or individual media concentrations in order to assess the magnitude of exposure, using the toxicological criteria (e.g. MAC values or guideline doses), separately for all chemicals classified in the three categories listed above.

Having completed these two steps the aggregation process begins. To implement this process the magnitude of exposure expressed by multiplicity of exceeded allowable levels must be converted into indicators. After standardisation, the indicators are aggregated to produce exposure indices separately for the three categories of chemicals (irritating, systemic and carcinogenic).

These three kinds of numerical indices could specify the combined exposure for individual persons. As the guideline values were used in developing the indicators, the indices would also possess guideline values to facilitate the estimation of combined exposure excess.

Applying this system it would be feasible to define the value of combined exposure for each person, taking account of all sources of toxic substances, pathways of human exposure and routes of absorption.

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