Chemical risk. Assessment and management

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Please cited as: CHEMIK 2010, **64,** 12, 799-810

Introduction

The word risk is used for many everyday situations. This term is commonly used to specify many situations or states, such as: the state of emergency, the occurrence possibility of an unforeseen event, the possibility of suffering a loss or obtaining a result different than expected.

Generally, the risk is an indicator of a state or an event which can cause some losses. It is commonly understood as the measure of hazard or danger, which result from either probable events that are independent of us or possible consequences of taking a decision. So, by taking a decision in the situation recognised as the risky one, we consider both the occurrence possibility (probability) of such an event and the quantity of losses that it can cause. The higher the occurrence possibility, i.e. the probability of such an event and the bigger loss is, the higher the risk is. Such an evaluation is to provide an answer to a key question: whether to take a risk and thus, enter into the danger zone or not? Each of us has to answer this question in everyday situations. And we just make decisions on our own, usually using the intuition, less often on the basis of our own experience. Such individuality is reflected in our attitude towards the risk. As a consequence, our reactions to different types of risks are rather influenced by psychological factors, and some fears are very specific to particular forms of risk.

This problem is getting much more complicated if we are or we are bound to find ourselves in the risky situation. In other words, when we to some extent are forced to take a risk, regardless of our individual assessment of such a risk. Such situations are characteristic for the modern life, where many undertaken actions and made decisions are regarded by the society as connected with the risk. Consequently, more and more people are anxious about the risk. They perceive themselves be exposed to very serious risks, more serious than the ones faced by people in the past. And the majority of opinions express that this tendency is getting worse rather than better.

This is caused by an increasing public interest in life quality, which can be generally specified as the sign of desires related to the life free from unintended or uncontrolled risk. And this is reflected in:

- public demands for safer conditions at work, cleaner environment, safer food and products of everyday use
- the increase in the frequency of requests for explaining whether actions related to the risk are acceptable for the society
- higher emphasis upon a new attitude of legal regulations of a risk.

However, on the other hand, it may seem paradoxical, the expectations and demands of the society for increasing life level require, and even necessitate, the introduction of new technologies and products. This does not always correspond to increased safety. In many such cases, this is related to a new type of risk, and the danger cannot be eliminated by adequate safety precautions.

Nowadays, such a difference between the necessity to take a risk and public attitude has a decisive impact on both the risk assessment and decisions on further course. The risk assessment cannot be only based on individual feelings or experience, but it also has to involve techniques and methods, which at present state of knowledge, estimate the real hazard and indicate the methods of its elimination, or at least reduction.

Chemical risk

Widely understood chemization of life, and thus the presence of increasing quantity of chemical compounds in the surrounding world is an element of our life, which is commonly recognised to pose a risk for human health, and even life. Although chemicals produced by people are widely used in everyday life and provide significant benefits for the modern society, they are very often regarded to be the source of any possible disease, from various kinds of allergies to tumours.

Chemical hazards are associated with the risk, which harmful effects are not always well known, distant in time and forced, not voluntary. Such a situation arouses public anxiety and demand for repairing the status quo. The majority of fears focus on the nature and scale of risk related to chemicals, and its possible avoidance or at least reduction.

Although such fears are not always justified, as not all chemicals and not always cause a hazard, their increasing contribution in our everyday life and possible undesirable side-effects cannot be disregarded. Many substances, which were previously considered to be neutral or harmless for health, induced unexpected harmful effects. Thus, it is obvious that the assessment of a type and a scale of hazards created by the chemicals and the related risk of producing side-effects are required. Consequently, the developed countries have introduced legal systems to eliminate, or at least minimize, the risk of producing and using the chemicals even though the knowledge on harmful effects of many substances is still limited. The risk assessment is the measure which provides the realization of such an objective. Such an assessment has to be conducted in accordance with the valid laws of the European Union, which provide the risk assessment at every stage of the production process and chemicals usage and for different conditions of human or environment exposure to the chemicals, and in the first place to monitor their concentrations at safe level.

Types and sources of chemical hazards

The chemicals risk result from the fact that chemical compounds can enter the environment not only from the production processes, but also from products. As a result, the chemicals along with their degradation products appear in the increasing quantity in the air, water and soil, and finally they can enter a human food chain. Moreover, some of these compounds are very stable and can be transported from the emission source at great distances. This situation creates hazards which can appear in many areas, and thus, human populations and the environment are endangered.

The chemicals are characterized with the possibility for inducing harmful effects at people, or elements of the environment, but also with the nature of such interactions. They are specific, i.e. induce determined effects and:

- can be present in the direct vicinity of the emission source and in a significant distance from it
- can occur immediately or after some time (e.g. due to self-defence ability of an organism)
- different groups of people or species of animals in the environment can be exposed in another way
- concerning the future, they are related to the determined occurrence probability, however there is no certainty if they appear at all or what their impact effects are

- some effects are irreversible, others can be reversed in a natural or artificial way.

Thus, the final effect will be the result of combining these specific features and the nature of their impacts.

Chemical risk assessment

Objectives and the scope of chemical risk assessment

The overall objective of assessing every kind of the risk is to find answers to the following questions:
1. What is the probability of an occurrence of a given event?
2. If the event occurs, what will be the scale of its harmfulness regarding quantity?

For the assessment of risk induced by the chemical substances, it is assumed that the related hazard has already occurred or will occur in the future, i.e. when it is assumed that such substances have already been or will be used. Therefore, the occurrence probability for chemical substances is not specified, but the scale of existing or expected hazard is determined and compared with the hazard which does not cause any negative effects.

The risk related to che mical substances depends on the following factors:

- the amount of the chemical compound in the product or the environmental medium (water, air, soil)
- the duration of human contact (exposure) with the product or polluted environmental medium
- toxic properties of a chemical compound.

For chemical hazards, the risk assessment for human health is to evaluate the nature and occurrence possibility of adverse health effect at people, who can be exposed to the chemicals present in the products or the environmental media now or in the future.

The risk assessment has to provide answers for many questions to explain the above. They are, e.g.:

- Which chemical compounds will people be/ are people exposed to? What is their concentration level and exposure period?
- What type of health problems can result from using the considered chemical compounds?
- Is there any level of concentration below which these chemical compounds do not carry a risk for health?
- Are there people or groups of people who are more susceptible to effects of considered chemical compounds while taking into account the following factors: age, genetics, previous health conditions, ethnic practices, gender etc?
- Are there people or groups of people who are more susceptible to some compounds due to such factors as: the place of work, rest, diet etc?

The answers to such questions are useful in understanding and evaluating the meaning of chemical exposure and related risk to human health. They are to provide information on the need and type of protective measures.

The scope and nature of risk assessment are very wide – from impacts on large populations of people (e.g. at the national level) to impacts in specific local conditions. Some assessments are retrospective, i.e. they concentrate on already existing damage or harms, other try to predict future possible hazards to human health or the environment, e.g what the expected risk is if a new pesticide is approved to be used in the cultivation.

Valid procedures for chemical risk assessment[1]

The risk assessment of chemical substances consists of four subsequent stages: (1) risk identification, (2) assessment of dose-effect relationship, (3) exposure assessment, and (4) risk description.

1) The control of risk level for chemical substances, which is obligatory in the European Union, included in Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), and the procedure for conducting risk assessment included in Technical Guidance Document on Risk Assessment, Brussels: The European Commission, 2003

1. Risk identification

Potentially harmful health effects, which can be induced by a specific substance, are identified using all available data.

The effects related to both toxic and physical and chemical properties of substances are considered. The hazard related to the following groups of potential effects is identified:

- irritation
- allergies
- corrosivity
- acute toxicity (after a single exposure)
- toxicity of long-term doses
- carcinogenicity
- mutagenicity
- reproductive toxicity.

Types of effects are determined on the basis of adequate tests (this particularly refers to new substances); available databases can also be used.

2. Assessment of dose (concentration) – effect (response) relationship

When the risk is identified, the next step is to determine the relationship between a dose (quantity of substance intake during the specified period) or the exposure level (direct contact in a specified period) to a given substance and the scope as well as the acuity of the effect induced by it, or the response of an organism.

Regarding the effect of chemicals on the organism, they can be divided into two groups. Chemicals inducing adverse health effects which are not exhibited until a given substance or an active metabolite do not reach the threshold level of concentration in an organism, can be classified into the first group. Reaching the threshold concentration is connected with the exposure level of an organism (human or tested animal) to a given substance. In other words, the threshold level of exposure has to be reached before the effect is induced. For these chemicals, this stage is aimed to determine threshold values of a dose or concentration. They are determined from a dose-effect graph, which illustrate the relationship between the dose amount and the scale of induced biological changes, e.g. changes in body weight, blood pressure, the level of enzymes produced during the increasing dose or increased irritation of skin.

For this purpose, all available data on dose (concentration) – effect relationship are used, i.e.:

- human data (tests, data from exposure of people at occupational risk, reports from accidents etc)
- non-human data (tests on animals)
- relationship between the compound structure and its activity.

Exposure routes, duration and frequency are probably included in the determination of threshold values. Depending on the purpose and scale of the assessment, it can be necessary to specify these relationships for all or selected social groups, such as workers, consumers, people exposed indirectly *via* the environment, and even such groups as the elderly, children or pregnant women.

The compounds that cause adverse effects at every dose or concentration, e.g. not characterised with the threshold value, are classified into the second group. There are compounds, which interact through mechanisms, for which threshold values (carcinogenicity, mutagenicity and reproductive toxicity) cannot be identified. For such compounds, the relationship between a dose (concentration) – response is determined. In this case, it is the number of individuals in a tested population who demonstrate a given effect, e.g. the number of dead individuals or individuals with cancerous changes. This relationship can be identified as the graph of effect occurrence probability to the dose.

3. Exposure evaluation

Exposure is understood as the direct contact of an organism with a chemical, physical or biological factor and determines the quantity of a given factor absorbed by the organism. For chemical compounds, this corresponds with the quantity of a substance absorbed with food, including water, with the total quantity of a substance being in contact with skin (calculated from the quantity that is in contact with the individual surface) and, depending on the needs, the quantity of a substance absorbed with air through inhalation or its concentration in the air. If the exposure occurs through many routes, e.g. with food and inhaled air, the total burden of the organism should be determined. The exposure is considered as a single event, the series of events (including frequency and duration) or the continuous exposure.

The exposure is evaluated by estimating the substance dose, which a given population is or could be exposed to. Such populations can be very general, as the whole society for some widely distributed materials (e.g. food additives, specific hygiene measures, products of household chemistry) or very limited, as some users or workers (e.g. producing or using pesticides).

The questions that arise during the exposure analysis include a probable source of pollution (gases from incineration plants, waste effluents from a factory, the application of pesticides), its concentration at the emission source, its distribution routes in the environment (environmental media, products) – from the source to the exposed population, and the current level in the exposed organism, The exposure evaluation involves many types of information, including the information on lifestyles of a given population.

The following human populations are considered (assuming that each of them could be exposed through inhalation, oral or dermal route): workers, consumers, people in general from an evaluated area.

Workers

The exposure evaluation for people who, due to their occupation, are connected with chemical hazards at places related with the production is relatively the simplest. It covers a small population which is slightly diverse regarding age and health. Although the substance can enter the organism through the respiratory, digestive system or skin contact under such conditions, the real routes of exposure, like the quantity of an inhaled substance, are or could be generally properly identified. In practice, they are the respiratory system and skin contact, and the quantity of absorbed substance and temporal characteristics can be easily determined from measurement data.

Consumers

Consumers belong to the second group which is exposed to chemical compounds. A consumer, i.e. a member of a local, regional or even national community, of any age, gender and health condition can be at risk of exposure by the usage or use of products that are available on the market. Both chemical substances and products containing them can be classified as products. And the product itself, or the substance, can be used for more than one purpose. Consumers are assumed to be liable to all types of exposure, i.e. oral, dermal and inhalation. Thus, the exposure evaluation of consumers is very restricted because it cannot be monitored or controlled after the product sale. For that reason, only data characterizing average situations can be involved in the exposure evaluation. The required data include:

1) data on contacts with the product:
- the frequency of product use
- one-time use of the product
- the place of product use, including the room size and air exchange rate.

2) data on concentration:
- substance mass content in the product
- substance concentration in the product at a specific way of using it, e.g. after diluting, evaporating.

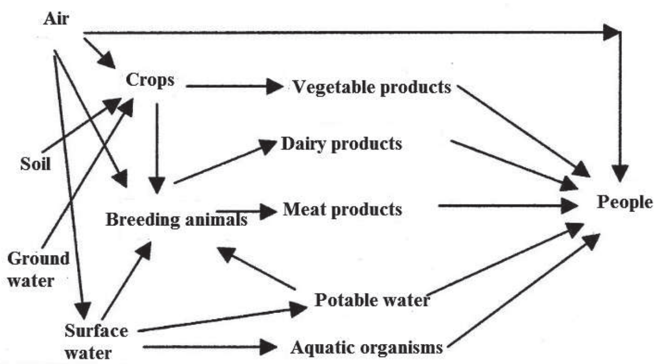
3) data on using the product:
- physical state of a product (gas, liquid, powder, crystals, aerosol etc)
- quantity of one-time consumed product
- contact surface with the product
- intended use of the product.

4) likely exposure of other people, including children, during using the product.

A variety of products and their applications cause that required data on exposure values are usually unavailable, and the most preferably available data are fragmentary and not confirmed. Therefore, the following elements are considered during using these data:
- if the measurement data are representative for the exposure of a whole tested group of consumers?
- if they reflect a real scenario of exposure?
- if they describe the predictable use of a product?
- if they reflect a whole range of expected exposures, only its part or a single value?

People exposed through indirect routes via the environment

The same or even greater level of difficulty is related to the risk assessment for people exposed through indirect routes via the environment. The exposure is likely through food consumption (meat, cereal, diary products, fish, fruit, vegetables etc), potable water and inhalation. Scheme 1 illustrates different exposure routes.



Scheme 1. The scheme of exposure routes for people through indirect routes via the environment

Scheme 1 demonstrates that the concentration in the air, soil, ground and surface is crucial. This is the component of the environment, where the pollutants are introduced and from which they enter a human organism through different routes. The values of concentration can be obtained from direct measurements. But it is usually calculated by means of available models that use physical and chemical properties of substances, particularly coefficients of interphase distribution. The calculations take into account that values of concentration in taken media is influenced not only by the concentration at output centres of the environment, but also by pathways and the dynamics of substance transport to other centres as well as by their reactions and transformations.

The exposure is determined according to the following procedure:
- the concentration of substance in taken media (food, potable water, air) is estimated
- daily intake of each medium is estimated
- the quantity of substance intake with each medium is calculated.

Exposure through the respiratory system

This route of exposure can be a considerable part of the total exposure to volatile compounds. Their concentration in the air can be either measured or calculated from the distribution models of gas pollutants in the atmosphere. However, values typical for different types of activities and particular age groups are assumed for the volume of inhaled air.

But it should be emphasized that the real scenario of exposure, i.e. whether this is continuous, short-term, year-long or seasonal exposure etc, has a crucial impact (apart from concentrations) on the quantity of a substance which enters the organism via this route.

Exposure through potable water

Potable water can be prepared from both types of water: ground and surface water which can be polluted - ground water with compounds released from surface layers of soil, and surface water with directly and indirectly introduced chemical compounds. At insufficient efficiency of purifying methods and inadequate monitoring, the compounds can enter the water supply systems (this particularly concerns organic compounds).

The quantity of consumed water is assumed at levels typical for particular age groups. For example, the average value for adults is 2 dm^3/day, and for children this value is adequately lower depending on the age.

Exposure through food

Direct measurements of concentrations in the foodstuff create no technical problems, whereas they are of little usefulness and can be used for exposure evaluation only in few cases. This is caused by significant discrepancies in measurement date for the same products. Therefore, the available models are used for estimating the concentrations in the foodstuff. These models allow for calculating the concentration in the product on the basis of the concentrations in the air, water and soil. Besides the concentrations in fundamental components of the environment, the additional parameters characteristic for the transportation process of chemical compounds into the product are used in the models.

It is quite difficult to estimate exposures for vegetable products which constitute the main foodstuff for both people and animals. Such difficulties result from a wide variety of cultivated plants and fruit, various conditions of their exposure to chemical substances, diverse uptake of substances from the environment by individual parts of plants and from different parts of plants used as food. For this reason, the concentrations in plant materials are calculated with division coefficients of a given substance as the average values for specified groups of plants or their parts.

Due to the diversity of quantitative and qualitative content of consumed food, a standard nutritional basket is assumed in order to evaluate a total daily dose, i.e. the exposure to a given substance.

Generally, due to insufficient knowledge and lack of data on penetration processes, methods based on models provide estimated values which are usually encumbered with a high uncertainty level. Nevertheless, it is the only way to estimate the exposure through foodstuff in many cases.

The presented procedure demonstrates that the exposure evaluation is the main, and simultaneously the most difficult stage of risk assessment. These difficulties originate not only from the variety of objects and situations, but also they are usually created by too few or none data. As different populations of people (workers, consumers, people in general from the specified area), can be liable to the exposure, its (concentration) levels should be specified for each of these groups, and very often for sub-populations within these groups. The following factors should be regarded: frequency and duration of exposure, exposure route, people practices and habits etc. Further, the spatial scale of exposure (personal/local/regional) should be also included. Consequently, we usually obtain the range of exposure levels, and not a single value. It is important that the obtained levels reflect the situation which is characteristic for them.

4. Risk description

At this stage, the risk and acuity of probable adverse effects on a given population of people, which result from the current or expected exposure to a given substance, are assessed.

Although each of previous stages of analysis uses all available data and information describing each type of hazard, dose-effect relationship and exposure, none of them provide conclusions about the general risk. This task is reserved for the final stage, where each information, data and conclusions from previous stages are analyzed jointly

For this purpose, quantitative comparison of the information on expected exposure and the value of concentration or dose, which does not induce the adverse effect yet, is performed. This comparison is made separately for each population liable to exposure and for each adverse effect. The above requires the concentration on the effects which can be revealed at expected levels of exposure. Two cases are possible:

1. Expected exposure is lower than the threshold value

$$\frac{\text{Expected exposure}}{\text{Threshold value}} < 1$$

2. Expected exposure is equal to or higher than the threshold value

$$\frac{\text{Expected exposure}}{\text{Threshold value}} = 1 \text{ or } > 1$$

If the expected exposure is lower than the threshold value (case No. 1), it can be generally assumed that no hazard occurs. However, it should be considered whether the safety margin is sufficient. For this purpose, the following elements should be regarded: uncertainty over the quality of used data, nature and intensity of the effect, a type of exposed population, the nature of exposure (route, duration, frequency).

When the expected exposure is equal to or higher than the threshold value (case No. 2), the actions should be undertaken in order to eliminate, reduce or solve in another way problems related to the risk. It is usually recommended to reduce the risk by introducing measures that decrease the exposure. In some situations, especially at high threshold doses and minor excesses as well as uncertain data, an attempt can be made to reconduct the exposure evaluation on the basis of extra data.

Chemical risk management

The risk assessment provides information on a potential risk to human health or the environment, and the term "risk management" defines actions that are undertaken to protect them.

For chemical hazards, a risk manager can take two types of decisions, i.e.:

- reject the planned or existing hazard if the related risk is unacceptable
- accept the planned or existing hazard on the condition that the risk is decreased or eliminated, e.g. the reduction of hazard or exposure, the decrease in risk consequences etc.

In the first case, eliminating the risk completely means the prohibition against the marketing of a chemical compound or its withdrawal from use. For a long time, many decisions have been made which cause that many chemical compounds are withdrawn from use.

Very often, or at least not nowadays, it is not possible to withdraw a compound from use. Then, the risk management is focused on the reduction of risk. Such actions usually result in decisions (or permissions) on the allowable quantity of substance to be released with industrial wastewater to a river from a specified plant, determining substances which can be stored at an internal waste disposal site, conditions for storing hazardous waste, determining the permit requirements for unloading, storing and transporting chemicals, determining national standards in air quality, specifying acceptable levels of pollutants in potable water.

Every decision, especially if it covers a transregional area, has to consider additional elements, which are not included in the risk assessment itself, especially data on economic issues, informing the risk manager about the risk costs and benefits of its reduction, costs of risk mitigation, corrective options, effects of costs distribution and benefits for the society, as well as technological factors, including feasibility, effect and the scope of options for risk reduction.

While taking decisions on allowable levels of doses or concentrations, the analysis and evaluation of data uncertainty, which were used in the risk assessment, is crucial. These uncertainties can be caused by many sources, real and inherent changeability of data in time, changeability in measurements accuracy and elaborating data, gaps in knowledge which result from the lack of data, assumed models and procedures for tests that do not precisely reflect the exposure of regarded population, and, what is the most important, changeability in intra- and between species. The latter kind of changeability refers to the transmission of data obtained from animal tests to people.

As the risk assessment can be subject to uncertainties from many sources, the risk reduction is the most commonly applied measure. It is based on introducing so-called coefficients of uncertainty which allow for determining allowable levels of doses. Their values are within range of 10 – 1000 depending on used data. Thus:

- a level lower by 10-fold than the threshold value from tests is assumed to be acceptable on the condition that these data are obtained from long-term human tests. This takes into consideration the real changeability in susceptibility of human populations
- a level lower by 100-fold, and even 1000-fold, than the threshold value from tests, providing the data from animal tests are transmitted to human populations, the data are derived from a small number of individuals and/or a small database.

The uncertainty coefficients are not used for chemicals with a particular effect, for which threshold values (carcinogenicity, mutagenecity and reproductive toxicity) cannot be identified. As it has been mentioned, the occurrence probability of effect, which depends on the absorbed dose of the compound, is estimated for these compounds. This is usually applied for substances regarded as carcinogenic. For this purpose, the quantity of cases from the tested population which exhibit a defined effect in relation to the quantity of the whole population for different doses is used. If the substance, and simultaneously the risk, cannot be withdrawn from use, the level of its concentration which corresponds to a risk of 10^{-6}, i.e. the occurrence of one additional case of tumour per 1 million people exposed to the compound during their whole life, is acceptable.

It should be emphasized that the uncertainty coefficients should not be applied mechanically. The decision on introducing such a coefficient and its scale has to be preceded with the uncertainty analysis of all data and information used in the evaluation, both to protect the most susceptible groups in the society and provide the realization possibilities. However, the safety issues could require very low threshold doses, and thus, very low concentrations of chemical compounds, which are hardly obtainable or even unobtainable due to technical and economic reasons.

Does chemical mean hazardous?

The assessment of chemical risk, as the information source of chemical hazards and related occurrence possibility of adverse health effect at people, is helpful for people or decision bodies – representatives of authorities or manufacturers of chemicals, in determining priorities for undertaking preventive and corrective measures, their type and range – in order to monitor the chemicals level in products or the environment. This is not the only tool. A system of registration, evaluation, authorisation and restriction of chemicals (REACH) implemented in the European Union, regulations for manufacturers of drugs, food additives, plant protection products, and acceptable values of gas emissions to the air, or the quality of discharged waste set very strict requirements for chemicals production and use. Due to all actions undertaken in order to reduce the chemical hazard, it can be stated that any other hazard of modern life did not involve so much attention, effort and costs of its reduction as the chemical hazard. We cannot neglect or underestimate these effects.

However, the actions do not allow for stating unambiguously that the situation connected with chemical hazards has been controlled or is almost controlled, and the related risk is slight. The chemicals, as everything, can create the risk. But the application of chemicals has been aimed to improve living standards, and particularly eliminate other hazards that used to ravage countries and decimate the populations. There are many examples:

- using chemicals in the agriculture – this is commonly considered to be very harmful and very risky to human health. Due to the introduction of fertilisers and plant protection products, the intensification of agriculture provided the increased food production which prevented famine in many places all over the world, and the decrease in crop areas that resulted in the reduction of the environmental burden.
- chlorine –it is a very reactive and toxic element that creates a relatively high hazard for people and many components of the environment. This put forwards demands on its elimination from use. However, using chlorine and its compounds for disinfection, particularly of potable water, has practically eliminated the risk of epidemics induced by unsatisfactory sanitary conditions at global scale.
- many organic compounds of chlorine are hazardous to health and their use not only in the original form, but also to manufacture other products, can be too risky – this justifies the demands on its withdrawal. But such compounds are necessary to produce many essential goods, including drugs or plastic.
- in recent decades, the quantity of municipal waste, including a considerable number of plastic wastes – particularly polyvinyl chloride, has dramatically increased. None of methods of their disposal involving acceptable solutions from technical and economic point of view was proposed so far. Therefore, there are more and more, both legal and illegal, waste disposal sites which create a serious hazard to the environment, and consequently, to human health. But plastics, such as polyvinyl chloride, are a significant element of the modern life. And the withdrawal from use or its limitation would signify the regression of civilisation.

Thus, the chemicals cannot be perceived only from the point of view of the risk connected with them. Those who demand their withdrawal from production and use do no take into account the consequences of such decisions, i.e. the risk of inducing effects at the range and scale that are difficult to predict. Not all chemicals, and not always, cause hazard to human health. The issue whether to use them is not a problem. The most important is whether we use them in a responsible way and what benefits they bring. Even if a chemical compound has dangerous properties, the risk for people and the environment is very low at safe applications, in moderation and under controlled conditions.

Prof. Stefan ZIELIŃSKI is a graduate of the Faculty of Chemistry at Wrocław University of Technology (1959) with the specialization in "Reactor Materials". At first, he started his job in the Department of Inorganic Technology which, after the reorganisation of the Wrocław University of Technology (WUT) in 1969, was changed into the Institute of Inorganic Technology and Mineral Fertilisers at WUT. In 1968, he was awarded the academic degree of doctor of chemical sciences for his doctoral thesis on *Research on concentrated artificial fertiliser based on glassy sodium metaphosphate*. In 1981, he was awarded the academic degree of habilitated doctor of technical sciences for the thesis on *Kinetic aspects of the crystallization of gypsum in the process of extraction phosphoric acid formation*, and in 2001, he was awarded the academic degree of professor in technical sciences. The scientific achievements of Professor Stefan Zieliński cover the total number of 189 papers, including 103 published papers. During his career at the Chemical Faculty, Wrocław University of Technology, he held, inter alia, the positions of: the Deputy Director of the Institute of Scientific Research and Cooperation with Industrial Sector (1978-81, 1981-84 and 1987-1990); the Deputy Director of Research Staff Development and the Manager of the Department of Chemistry and Inorganic Technology (1991-1996). He was also the member of Scientific Committees of I-IV Congresses on Chemical Technology.

He elaborated and conducted many lectures, at first specialised ones, and then comprehensive ones for the whole faculty. In 1986, he organised a national conference on new ideas for teaching chemical technology, at which he presented a programme paper on *Problem based teaching of chemical technology*. He developed some assumptions and prepared *Technology of Environmental Protection* specialization programme, for which he published a book "Chemical contamination in the environment." In 1996, he organised the international workshops Advanced Research Workshop *Environmentally Benign Chemical Technologies*, (Co-director). For many years, he was a member of the Commission on courses curriculum of Chemistry Faculty Board, WUT, and Educational Commission of the Faculty Board. He was also the Manager and President of the Council for Chemical Technology specialization, which is among two specializations at Wrocław University of Technology that have been distinguished by the State Accreditation Committee.

During his work, he was the supervisor of ca.50 MS theses. Professor Stefan Zieliński supervised 3 doctors, elaborated 3 reviews of habilitation theses, 7 reviews of doctoral theses and 8 reviews for publishers.

For his remarkable educational work and high level of conducted lectures, Professor Stefan Zieliński was given 3rd Level Team Award from the Minister of National Education, the Award from the Senate of Wrocław University of Technology, many awards from the Chancellor of WUT and the dean of the Faculty of Chemistry, WUT.

Professor Stefan Zieliński has been the President of Programme Board for the monthly magazine CHEMIK nauka•technika•rynek (CHEMIST science-technique-market) for 10 years. He is the author of many initiatives, which are successfully presented in the magazine, the author of publications in CHEMIK magazine as well as the coordinator of technical issues in editions on the sustainable development.

He was honoured with the Order of Polonia Resituta Knight's Cross, Gold and Bronze Cross of Merit, the Wojciech Świętosławski Medal and SITPChem (Association of Polish Chemical Engineers) Honourable Award.

SŁONECZNA CHEMIA

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- **Scientific-Technical Conference of the series Chemical Industry Challenges and Barriers** – 20 - 22.11.2010, Ustroń-Jaszowiec
- **III International Fair and Conference of Chemical Industry EXPOCHEM 2010** - 23 - 25.02.2010, Katowice
- **Chemicals 2010** - 8.06.2010, Gliwice
- **Museums Nights** – 15 - 16.05.2010, Warsaw
- **XIV Symposium Application of spectroscopic methods in the study of materials and organic compounds** – 27 - 29.05.2010, Poznań
- **Chemist's Day** - 9.06.2010, Wrocław
- **53rd Congress of PTChem SITPChem** – 14 - 18.09.2010, Gliwice
- **29th General Congress of SITPChem** – 22 - 24.09.2010, Toruń

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