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ESTIMATION OF ECOLOGICAL HUMAN HEALTH RISKS BY INFLUENCE OF NON-THRESHOLD TOXICANTS

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Abstract. *In the article is considered an important problem of ecological danger – quantitative calculation of non-threshold toxicants influence on the human as risks. The basic pollutants are vinyl chloride, arsenic and dioxins. The correspondent risks are calculated on the base of safety record definition. For complex approach of ecological danger determination is applied the additive model of risks calculation that is a good instrument for danger level definition. In addition, in this work is used the synergism occurrence that can have significant impact on the correspondent risks value. We considered different types of synergism, which influence the risks values of harmful impact of the chosen non-threshold pollutants. This impact is represented through number values of synergism coefficients. It is considered the situation of both inconspicuous synergism and enough real. In these cases the meaning of risks differs from each other essentially. This way of the risks values calculation permits to estimate the danger level of some carcinogens impact on the human health adequately.*

Keywords: human health hazard; demercurization; mercury; mercury light sources.

1. Introduction

In modern industry it is used a great number of chemical substances both for raw materials and as finished goods for customers. As waste many substances get into waste landfills and into effluents, causing increase of environmental pollution. As a result, water and food products become polluted. In connection with this, it raises the question about quantitative aspects of different environmental components, including quantitative meaning of the negative factor. Besides, it is necessary to be able for foreseeing probability of any pollutant influence. For solution of these tasks about interrelation of pollutants and environment it can be used an approach, based on quantitative estimation of ecological risks of any pollution influence on human health.

2. Analysis of the latest research and publications

The environmental impact estimation as a stage of ecological projecting was formed in the early 1970s, starting from adoption of the National Environmental Policy Act in the USA in 1969 [1]. Since it became a strong instrument widely used in more than 100 countries of the world. However, systematic study of ecological effects was conducted from the middle of 1980s [2]. On the modern stage of society development it raises the question for understanding of fundamental mechanisms of quantitative risks meaning that is a key moment for making of certain management decisions.

3. Aim of the work

The aim of the work is to investigate negative influence of some carcinogens on human health. The corresponding risks were determined as an example of vinyl chloride, arsenic, dioxins, getting into the human organism with water.

4. Risks estimation of negative influence of carcinogens

Carcinogens include substances, their influence significantly increases frequency of tumor occurrence in populations of people (animals). By estimation of health risk, stipulated by influence of carcinogenic substances it is used two important statements. First, it is believed that carcinogens have no threshold dose, their influence starts from the smallest quantities, getting into the human organism. Second, it is considered that probability of oncological disease development (carcinogenic risk) is directly proportional to quantity (dose) of carcinogen, got into the organism. Combination of these two statements is described by so called non-threshold linear model.

Linear character of dependence between carcinogenic risk and dose of carcinogenic substance is expressed by formula

$$r = F_r \cdot D,$$

where r is an individual carcinogenic risk (it should be understood as additional risk to already existent possibility of cancer disease) of oncological disease caused by getting of certain carcinogen; D is a dose of carcinogen got into the human organism, F_r is a proportionality coefficient between risk and dose named as the risk factor.

Risk factor F_r shows how quickly probability of oncological diseases is raising by increase of carcinogen dose got into the human organism with air, water or food. The risk factor as a coefficient of direct dependence slope is also called "risk-dose". Accordingly, the more angle of slope, the more health risks.

The unit of risk factor F_r is $(mg/kg \cdot 24\, hours)^{-1}$, it is inverted to the unit of average daily entry of carcinogen. Quantitatively the risk factor characterizes increase of health risks, caused by daily entry in the quantity of 1 mg according to 1 kg human body weight.

Individual carcinogenic risk can be calculated according to the following formula

$$r = m \cdot F_r,$$

where m is average daily entry of carcinogen with air, water or food that is equal to 1 kg human body weight, in milligrams on kilogram during 24 hours $(mg/kg \cdot 24\, hours)$.

Let's consider the situation of drinking water, polluted with such carcinogens as dioxin, vinyl chloride and arsenic. The risk factors of these substances are described in table 1.

Table 1. Meaning of the risk factors by entry into the human organism with water

Carcinogens	F_r, $(mg/kg \cdot 24\, hours)^{-1}$
Arsenic	1,75
Vinyl chloride	1,9
Dioxins	$1,6 \cdot 10^5$

Arsenic. The arsenic compounds get into the human organism with mineral water, grape wines and juices, sea food, medical products, pesticides and herbicides. Arsenic is deposited predominantly in reticuloendothelial system. It is believed that optimal intensity of arsenic entry into the organism contains 50–100 mcg per day. Significant amount of arsenic is contained in cod liver oil and sea fish (up to 10 mg/kg), wines (up to 1 mg/l and more). About 80 % of arsenic is absorbed in gastro-intestinal tract, 10 % come through the lungs and about 1 % through the skin. In 24 hours after entry 30 % of arsenic comes out from the organism with urine and about 4 % with fecal. Arsenic is accumulated in the lungs, liver, skin and small intestine. Arsenic and all its compounds are poisoned. Vomiting, stomach ache, diarrhea and central nervous system depression occur by acute poisoning with arsenic. Similarity of symptoms to arsenic poisoning with symptoms to cholera let use arsenic compounds (often arsenic trioxide) as deathful poison for a long time as well.

On the territories where there is abundance of arsenic in the ground and water, it is accumulated in thyroid by people and causes hypothyroidism.

The poisoning symptoms are the following: metallic aftertaste, vomiting, intense stomach ache. Later these are cramps, paralysis and death. The most known and available antidote by arsenic poisoning is milk, namely main milk protein such as casein which produces insoluble compounds with arsenic and is not absorbed into the blood.

The arsenic poisoning happens by consumption of poisoned food and water, breathing in of arsenic compounds like dust in working conditions and application of some medical products. The target organs by abundant arsenic in the organism are bone marrow, gastro-intestinal tract, skin, lungs and kidneys. There are many evidences of carcinogenicity of inorganic arsenic compounds. The high mortality rate because of lung cancer is registered among workers employed in pesticides production, gold mining and melting of arsenic alloys with other metals as well as non-ferrous metals, especially copper.

Dioxins. Dioxins are the manmade compounds, although nobody has created this poison ever purposefully. Its appearance in environment is stipulated by development of different technologies, mainly in postwar period and is connected with production and using of chlororganic compounds and disposal of its waste.

Dioxins are the most dangerous for people as a very small dose is enough for affection of the human organism and dioxins come out from the organism very slowly. The living organisms come under dioxins influence through air (aerosols), water and food products. There are three sources of entry and accumulation of dioxins: food, air and chlorinated water.

Dioxins get into the cells without hindrance dissolving in fats easily. It causes metabolic, nervous system and hormonal disorders, changes of skin covering, adiposity. The heaviest consequences of dioxins influence are contribution of genetic mutations of the cells and development of cancer.

The main way of dioxins entry to the organism is a food chain. 98 % of dioxins come into the organism with food products, 2 % with air and less than 0,01% with drinking water.

Vinyl chloride. Vinyl chloride appears in environment only as a result of its emissions during production and processing. More than 99 % of emissions of vinyl chloride remain in the air. Vinyl chloride evaporates from the ground surface quickly, although it can get into the ground through ground waters.

Vinyl chloride has complex toxic influence on the human organism, causing damage of central nervous system, osseous system, system damage of connective tissue, brain and heart. It damages liver, causing angiosarcoma. It causes immune changes and tumors, gives carcinogenic, mutagenic and teratogenic effects. Many researches inform that influence of vinyl chloride on the human causes cancer in different tissues and organs, including liver, brain, lungs, lymphatic system (organs and tissues taking part in blood formation).

By solution of tasks connected with consumption of drinking water the average daily entry of m carcinogen with water on 1 kg human body weight it can be calculated according to the following formula

$$m = \frac{C \cdot \nu \cdot f \cdot T_p}{P \cdot T},$$

where C is a concentration of carcinogen in drinking water, *mg/l*; ν is a speed of water entry into the human organism, *l*/24 hours (it is considered that adult person drinks 2 liter water daily); f is a number of days in a year during which the carcinogen influence happens; T_p is a number of years during which polluted drinking water is consumed; P is average body weight of adult person (about 70 kg); T is average time of possible carcinogen influence, it means average life duration of the human (about 70 years).

By calculations of risks by consumption of water polluted with the correspondent carcinogens the following characteristics are chosen, described in table 2. If to consider the content of maximum permissible concentrations of these carcinogens in water, their average daily entry with water and the correspondent risks will be little during three years. The research results are described in table 3.

Table 2. Research characteristics

	C, mg/l	F_r, (mg/kg·24 hours)	ν, l/24 hours	f, days/ year
Arsenic	0,05	1,75	2	300
Vinyl chloride	0,3	1,9	2	300
Dioxins	$2 \cdot 10^{-8}$	$1{,}6 \cdot 10^{5}$	2	300

Table 3. Average daily entry of carcinogens and correspondent risks

	m, (mg/kg·24 hours)	*Risk* (3 years)	*Risk* (1 year)
Arsenic	$5 \cdot 10^{-5}$	$8{,}8 \cdot 10^{-5}$	$2{,}9 \cdot 10^{-5}$
Vinyl chloride	$3 \cdot 10^{-4}$	$5{,}7 \cdot 10^{-4}$	$1{,}9 \cdot 10^{-4}$
Dioxins	$2 \cdot 10^{-3}$	$3{,}2 \cdot 10^{-8}$	$1{,}1 \cdot 10^{-8}$

According to the table 3, it is known that with water more dioxins can come, less arsenic and the biggest risk for human health is entry of vinyl chloride. And it exceeds the value of allowable risk $1 \cdot 10^{-4}$ that is enough dangerous for human health.

As for today the condition of environment is critical, it means it can be observed the simultaneous content of many carcinogens in air and water, it is necessary to consider the additive model of risks calculation foreseeing some harmful factors. In our case

$$Risk = Risk_1 + Risk_2 + Risk_3 = 2 \cdot 10^{-4}.$$

But negative influence and correspondent risks can not only be added, but also strengthen harmful influence of one factor on another. In this case it is observed occurrence of synergism that should be also considered by risks calculation. Because in this situation the additive model of risks calculation can show underestimated results. Taking into account the capability of risks additivity and synergism effect that can be essential in real situations as well, the risk value of combined influence of some factors will be impacted by the synergism coefficient which can be calculated according to the following formula

$$k = \frac{Risk_1 + Risk_2}{\prod_i Risk_i},$$

where $Risk_1$, $Risk_2$ are the correspondent risks of two harmful factors, if the combined influence of two factors is considered. If to consider the synergistic effect of three or more factors, then in numerator can be accordingly three or a few summands. Depending on meanings of the synergism coefficient can happen the following:

$k < 1$ is observed occurrence of synergism;

$k > 1$ is observed occurrence of antagonism (when negative influence is decreased by simultaneous effect of a few factors);

$k = 1$ is observed additivity of risks.

For example, of small town in the quantity 10000 persons the research is conducted concerning calculation of risks value using the additive model of risks and occurrence of synergism with coefficient $k = 0{,}6$. The research showed the results stated in table 4, where $Risk_1$ is a value of risks including the additive model and $Risk_2$ is a value of risks including occurrence of synergism, n_1, n_2 is a correspondent number of the suffered during 1 year.

Table 4. Risks and number of the suffered from polluted water consumption (by synergism with coefficient $k = 0{,}6$)

	$Risk_1$	n_1 person	$Risk_2$	n_2 person
Arsenic + vinyl chloride	$2{,}2 \cdot 10^{-4}$	3	$3{,}7 \cdot 10^{-4}$	4
Arsenic + dioxins	$3 \cdot 10^{-5}$	–	$5 \cdot 10^{-5}$	–
Vinyl chloride + dioxins	$2 \cdot 10^{-4}$	2	$3 \cdot 10^{-4}$	3

According to the table, it is known that even by moderate synergism the values of risks and number of the suffered increase and during one year the number of the suffered can reach from one up to four persons. During ten years these values will be notably higher.

If the synergism coefficient contains a real meaning $k = 0{,}2$, the situation will be much worse. The research results are described in the table 5.

In this case, according to the table data, the danger level will be notably higher, because the values of risks will be higher and accordingly the number of the suffered during one year that will contain from two up to eleven persons.

Table 5. Risks and number of the suffered from polluted water consumption (by synergism with coefficient $k = 0{,}2$)

	$Risk_1$	n_1 person	$Risk_2$	n_2 person
Arsenic + vinyl chloride	$2{,}2 \cdot 10^{-4}$	3	$1{,}1 \cdot 10^{-3}$	11
Arsenic + dioxins	$3 \cdot 10^{-5}$	–	$1{,}5 \cdot 10^{-4}$	–
Vinyl chloride + dioxins	$2 \cdot 10^{-4}$	2	$1 \cdot 10^{-3}$	10

5. Conclusion

1. This research showed that the content of the stated carcinogens in drinking water can be rather dangerous. The most dangerous is the content of dioxins in water, in spite of the fact that they are poorly soluble in water.

2. Such estimation of ecological risks offers the opportunity to assess probability of consequences for the human in response to a stressor.

3. The estimation of risks will be very useful for the further project alternatives, choice of optimal project decisions, especially in carrying out the correspondent measures for minimization of risks.

4. The quantitative characteristics of risks from harmful influence of both non-threshold and threshold toxicants is one of the steps for the further ecological insurance.

References

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В. П. Петрусенко. Оцінка екологічних ризиків загрози здоров'ю людини при впливі безпорогових токсикантів

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У статті розглянуто важливу проблему екологічної небезпеки – кількісний підрахунок впливу безпорогових токсикантів на людину у вигляді ризиків. Основними забруднювачами були вибрані вінілхлорид, миш'як, діоксини. На основі визначення індексу небезпеки були підраховані відповідні ризики. Для комплексного підходу визначення екологічної небезпеки було застосовано адитивну модель обчислення ризиків, котра є зручним інструментом для визначення ступеня небезпеки. При цьому в роботі було використано явище синергізму, яке може значно впливати на величину відповідних ризиків. Розглянуто різні види синергізму, які впливають на величини ризиків шкідливого впливу вибраних безпорогових полютантів. Цей вплив було подано через числові значення коефіцієнтів синергізму. Було розглянуто ситуації як незначного синергізму, так і досить реального. Значення ризиків у цих випадках суттєво відрізняються один від одного. Такий спосіб обчислення величин ризиків дає можливість адекватно оцінити ступінь небезпеки впливу деяких канцерогенів на здоров'я людини.

Ключові слова: безпорогова модель; канцероген; комбінований вплив; ризик; синергізм.

В. П. Петрусенко. оценка экологических рисков угрозы здоровью человека при влиянии безпороговых токсикантов

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В данной статье рассмотрена важная проблема экологической безопасности – количественная оценка влияния безпороговых токсикантов на человека в виде рисков. Основными загрязнителями были выбраны винилхлорид, мышьяк, диоксины. На основе определения индекса опасности были подсчитаны соответственные риски. Для комплексного подхода определения экологической опасности была применена аддитивная модель расчета рисков, которая является удобным инструментом для определения степени опасности. При этом в работе было использовано явление синергизма, которое может существенно влиять на величину соответственных рисков. Рассмотрены различные виды синергизма, которые влияют на величины рисков негативного влияния безпороговых поллютантов. Это влияние было подано в виде числовых значений коэффициентов синергизма. Были рассмотрены ситуации как незначительного синергизма, так и достаточно реального. Величины рисков в таких ситуациях значительно отличаются друг от друга. Такой способ подсчета величин рисков дает возможность адекватно оценить степень опасности влияния канцерогенов на здоровье человека.

Ключевые слова: безпороговая модель; канцероген; комбинированное влияние; риск; синергизм.

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