Laboratory work 4 «Human health risk analysis under harmful chemical substance exposure in the environment».

The methods of human health risk assessment have been intensively developed lately in some European countries, Great Britain, USA, and Russia. The modern science testifies the absence of a threshold impact for a lot of chemical contaminants. Risk is the likelihood that a harmful consequence will occur as a result of an action. Human health risk assessment evaluates the probability of health effects as a result of potentially hazardous behaviors.

Traditionally, such assessments have focused on the probability of increased disease in human populations. The approach follows the four steps recommended by the United States National Academy of Sciences:

1. Hazard identification;
2. Dose-response assessment;
3. Exposure assessment;
4. Risk characterisation.

In this work students are required to analyze human health risk for a man living in a city (or settlement) during his lifelong under the action of harmful substances.

Students have to apply the common technique described in lectures and course manual.

1. Assume the first stage is danger identification has been carried out, on its base the dominated environmental pollutants have been revealed, in terms of which the risk assessment should be performed. In the appendix for the work there are the names and concentrations of substances selected for risk assessment. At this stage students are to describe the process of identification, which criteria are fundamental for composing the list of substances in terms of which the risk assessment should be performed, their toxic properties. The characteristics of their toxicity are to be found in the database. Suggest the possible sources of compounds found in drinking water or air.

2. The second stage is risk assessment. Calculate it according to theory given in the lecture. Estimate the risk of cancerogenic and/or non-cancerogenic effects at inhalation (with air) and/or peroral (with drinking water) intake of pollutants in to human organism at chronic effect. The results of this part are presented in the form of numerical values of individual cancerogenic risk and danger coefficient of all substances separately and totally. The total risks are calculated by adding the values obtained both in different environments and for different substances. But cancerogenic and non-cancerogenic risks are not added by no means! The reference data are given below.

2.1 Estimation of cancerogenic effects is a calculation of individual cancerogenic risk (CR).

According to Environmental Protection Agency USA Approach and Guideline of the State Committee for Sanitary and Epidemiological Oversight under the Russian

Ministry of Public Health, one mathematical formula that determines an individual cancerogeneous risk from chemical exposures is

$$R_{ind} = 1 - \exp^{(-SF \times LADD)} \quad (1)$$

R_{ind} – individual cancerogeneous risk,
SF - Slope Factor, or Unit Risk, $(mg/kg \times day)^{-1}$, reference data are used, Table 3;
LADD - Living Average Daily Dose, mg/kg x day,

At low values of LADD this formula is simplified

$$R_{ind} = SF \times LADD \quad (2)$$

2.1.1 At inhalation intake R_{ind} is calculated by the formula

$$R_{ind\ ing} = SF_1 \times LADD \quad (3)$$

SF_1- Slope Factor at inhalation exposure, reference data are used, Table 3;

At inhalation intake the Living Average Daily Dose (LADD) is calculated by the formula:

$$LADD = [\, C_{atm} \times CR \times ED \times EF] / [BW \times AT \times 365] \quad (4)$$

C – the average concentration of the chemical substances, affecting during the exposure, mg/m^3;
CR- Contact Rate, for inhalation affect – inhalation rate, m^3/day;
ED- Exposure Duration, years;
EF -Exposure Frequency, day/year;
BW – Body Weight, kg;
AT - Average Time, or average life expectancy, years

2.1.2 At carcinogenic intake with drinking water (peroral intake)

$$R_{ind\ wat} = SF_0 \times LADD \quad (5)$$

SF_0 = Slope Factor at peroral intake, reference data are used, Table 3;
At intake with drinking water the LADD is calculated by the formula:

$$LADD = [C_{wat} \times V \times ED \times EF] / [BW \times AT \times 365] \quad (6)$$

C_{wat}– concentration of substance in drinking water, mg/l,;
V – the value of daily water consumption, l/day
ED- Exposure Duration, years;
EF -Exposure Frequency, day/year;
BW – Body Weight, kg;
AT - Average Time, or average life expectancy, years

When solving the problem the standard exposure factors are used:

Exposure factor	Water Consumption	Contact Rate inh	Exposure Duration	Body Weight	Exposure Frequency,	Average Time
Designation	V	CR_{inh}	ED	BW	EF	AT
Numerical value	2,2	20	70	70	365	70
Units of measurement	l/day	m^3/day	years	kg	day/year	years

2.1.3 Total individual cancerogenic risk

$$R_{ind} = R_{ind\ \mathbf{ing}} + R_{ind\ wat}\ (7)$$

2.2 The non-cancerogeneous risk, or Index Damage (HQ) is calculated by the equation

$$HQ_{ing} = \mathbf{C}_{\mathbf{atm}} / RfC\ (8)$$

HQ_{ing} - Index Damage at inhalation intake
LADD - Living Average Daily Dose, mg/m^3,
RfC– Referent (harmless) concentration mg/m^3, reference data are used (Table 2)

$$HQ_{wat} = \mathbf{C}_{wat} / RfD\ (9)$$

RfD **–** Referent (harmless) Dose at chronic peroral intake, mg/kg , reference data are used (Table 1)

Total HQ = $HQ_{ing} + HQ_{wat}$

3.
3.1 Risk characteristic is made on the basis of comparison with risk acceptability criteria (Table). According to the Table in terms of risk assessment results (both cancerogenic and non-cancerogenic risk separately), determine the risk level and its acceptability.

3.2 What number of additional cancerogenic diseases per 100 000 population should be expected at the exposure of studied factors in the given residence area?

3.3. Calculate population risk.

4. Risk management. If risk is not acceptable develop the measures to decrease the risk level (administrative, legislative, research, engineering, political etc).

The report has to contain all necessary parts: title page, objective of the work, initial data, and the work procedure (the entire technique of risk analysis is described successively according to points 1 -4, all calculations, designation deciphering is necessary), list of references.

Problem.

Characterize cancerogenic risk at benzol exposure when entering human organism all his lifelong at inhalation intake as a result of chemical enterprise operation. Average daily benzol concentration amounted 0,074 mg/m^3 in air of the residential area. Solving the problem use the standard exposure factors. The population of the city is 670 000 people.

Solution

Characterize a risk means to determine its level. Cancerogenic risk assessment level includes the calculation of R_{ind} – individual cancerogeneous risk,

1. Substitute the numerical values and calculate LADD and R_{ind}

LADD benzol= (0,074 mg/m^3 x 20 m^3 x 70 years x 365 / 70 kg x 70 years x 365 = 0,021 mg/kg daily

2. R_{ind} = 2,7 x 10^{-2} x 0,022 = 0,000638 = 6,38 x 10^{-4}

3. The value of individual cancerogenic risk obtained accepts the probability of the fact that during 70 years it is possible for 6 additional cancer cases among the population to occur equal to 10000 people, exposed to inhalation intake of revealed benzol level. Per 100000 people approximately 60 additional cancerogenic diseases should be expected at the exposure of the studied factors in the given residential area.

5. Calculate collective risk

R_{col}= 6,38 x 10^{-4}x 670000 = 426

According to the classification there is the average level of individual lifetime cancerogenic risk at benzol exposure entering the body with automobile exhaust. The given risk level is acceptable for professionals, but unacceptable for population in general; such risks require some arrangements and planned curative measures in the condition of residential areas. Benzol contained in exhaust gases in comparatively low amount – up to 4%, is, nonetheless, one of dangerous components in the complex mixture of automobile exhausts. It is well known that benzol influences central nervous system, results in leukemia, according to classification of International Cancer Agency belongs to the 1-st cancerogenic group.

Possible measures for decreasing benzol air concentration: decrease in losses in gasoline distribution system, decrease in limited acceptable benzol concentration in non-ethylene gasoline etc.

Reference data

REFERENCE DOSES
AT CHRONIC PERORAL INTRODUCTION (Table.1)

CAS	Substance	RfD, mg/kg	Damaged organs and systems
71-43-2	Benzol	0,003	blood, CNS, hormone system, cancer
107-02-8	Acraldehyde	0,0005	blood, death
7440-43-9	Cadmium	0,0005	kidneys, hormone system.
7440-02-0	Nickel	0,02	liver, cardio-vascular system, gastrointestinal tract, blood, body weight
14797-55-8	Nitrate Nitrite	1,6 0.165	blood (MetHb), heart system
7439-96-5	Manganese	0,14	CNS, blood
7440-38-2	Arsenic	0,0003	skin, CNS, nervous system, cardio-vascular system, immune system, hormone system, (diabetics), gastrointestinal tract
7439-98-7	Molybdenum	0,005	kidneys
7439-92-1	Lead	0,0035	CNS, nervous system, blood, development, reproduction, hormone system.
50-00-0	Formaldehyde	0,2	gastrointestinal tract, CNS, liver, kidneys
7782-41-4	Fluorine	0,06	teeth, bones
16984-48-8	Fluoride, inorganic, easily soluble	0,06	teeth, bones
7782-50-5	Chlorine	0,1	mucous coat, immune system
18540-29-9	Chromium (VI)	0,003	
67-66-3	Хлороформ	0,01	liver, kidneys, CNS, hormone system, blood

REFERENCE CONCENTRATIONS AT CHRONIC INHALING EXPOSURE
(Table.2)

CAS	Substance	RFC,	Damaged organs and systems

		mg/m^3	
10102-44-0	Nitrogen dioxide	0,04	respiratory organs, blood (formation of MetHb)
10102-43-9	Nitrogen oxide	0,06	respiratory organs, blood (formation of MetHb)
107-02-8	Acraldehyde	2,00E-05	respiratory organs, eyes
106-99-0	1,3-Butadiene	0,002	reproduction, respiratory organs, heart-vascular system, blood, cancer
50-32-8	Benzapyrene	1,00E-06	cancer, risk 1E-5, 1 ng/ m^3, immune system, development
71-43-2	Benzol	0,03	development, blood, red bone marrow, CNS, immune system, heart-vascular system, reproduction.
7440-41-7	Beryllium	2,00E-05	respiratory organs, immune system (sensible)
	Suspended substances	0,075	respiratory organs, death.
7440-48-4	Cobalt	2,00E-05	respiratory organs
2228840	Oil and petroleum products	0,071	kidneys
7440-02-0	Nickel	5,00E-05	respiratory organs, blood, immune system, cancer, CNS
7439-96-5	Manganese	5,00E-05	CNS, nervous system, respiratory organs
10028-15-6	Ozone	0,03	respiratory organs
7439-97-6	Mercury	0,0003	CNS, hormone system, kidneys
22967-92-6	Mercury (1+)метил-ион	2,00E-05	
7487-94-7	Mercury (II) chliride	0,0003	
	Soot	0,05	respiratory organs, teeth
7439-92-1	Lead	0,0005	CNS, blood, development, reproduction system, hormone system, kidneys
108-88-3	Toluene	0,4	CNS, development, respiratory organs
108-95-2	Phenol	0,006	heart-vascular system, kidneys, CNS, liver, respiratory organs
50-00-0	Formaldehyde	0,003	respiratory organs, eyes, immune system. (sensible)

FACTORS OF CACEROGENIC POTENTIAL (Table 3)

CAS	Substance	Carcinogenic group according to IARC	Carcinogenic group according to EPA	SF_O(mg(kgxday))$^{-1}$	SF_I (mg(kgxday))$^{-1}$
630-20-6	1,1,1,2- tetrachloroethane	3	C	0,026	0,026
79-06-1	Acrylamide	2A	B2	4,5	4,5
107-13-1	Acrylonitrile	2B	B1	0,54	0,24
62-53-3	Aniline	3	B2	0,0057	0,0057
75-07-0	Acetaldehyde	2B	B2	-	0,0077
8006-61-9	Benzine	2B	B2		0,035
71-43-2	Benzol	1	A	0,055	0,027
7440-41-7	Beryllium	1	B1	4,3	8,4
7440-43-9	Cadmium	1	B1		6,3
7440-02-0	Nickel	2B			0,91
7440-38-2	Arsenic	1	A	1,5	15
7439-92-1	Lead	2B	B2		0,042
18540-29-9	Chromium ((VI)	1	A	0, 42	42
50-00-0	Formaldehyde	2A	B1	-	0,046

Risk level ranking

Risk level	R_{ind}	HQ	
Extremely high	10^{-1}	More than 5	Unacceptable neither for the population, nor for professionals. Other actions for risk decrease
High	10^{-1}-10^{-3}		Carrying out of emergency improving and other actions for risk decrease is necessary
Average	10^{-3}-10^{-4}	1 - 5	Acceptable for professionals and unacceptable for the population as a whole; occurrence of such risk demands planned improving actions in the conditions of the inhabited sites
Low	10^{-4}-10^{-6}	0,1 - 1	Corresponds to a zone of conditionally (admissible) risk; at this level the majority of hygienic standards recommended by the international organizations for the population as a whole is established

Minimum	Less than 10^{-6}	Less than 0,1	Corresponds to one additional case of serious disease or death per 1 million persons suffered from the effect. Such risks are perceived by people as negligibly small, do not differ from usual, daily ones. Do not demand for additional measures in their decrease, are subject to only the periodic control

Standard exposure factors
Data for calculation

Number of variant	Name of settlement (city)	Population, th. people	Concentration of prior pollutants in the environment	
			Air, mg/m^3	Drinking water, mg/l
1	Tomsk	620	Formaldehyde – 0,0072 Toluene – 0,065	
2	Novokuibyshevsk (Samara Oblast)	470		Arsenic - 0,005 Chromium – 0,03 Manganese – 0,28
3	Kuibyshev region of Samara city	780	Acraldehyde – 0, 000035 1,3 – butadiene - 0,03 Soot – 0,08	
4	N city of Samara Oblast	870		Lead – 0,46 Cadmium – 0,013 Molybdenum – 0,08 Nickel – 0,1
5	Strezhevoy (Tomsk Oblast) ground water of the Ob-Tomsk interfluve before entering the distribution network	280		Nitrate -2,4 Fluoride – 0,33 Manganese -0,09 Residual chlorine -0,72
6	Aktobe (Kazakhstan)	760	Lead -0,00377 Benzol – 0,074	
7	Aktobe (Kazakhstan)	760	Lead -0,00053 Benzol – 0,074	

8	Novosibirsk	1100		Arsenic – 0,0004 mg/l Lead – 0,003 mg/l Trichloroethene – 0,03 mg/l
9	Pervomaiskoye settlement according to Vidyaikina's data	6000		Nitrate -0,26 Nitrite 0,42 Manganese – 0,52
10	V city	55	Benzapyrene 9,4E-10 Nickel 7,8E-08 Cadmium 1,4E-08	
11	V city	55	Lead 2,4E-08 Arsenic 3,5E-09 Hydrogen oxide (II) 0,00061	
12	Tomsk	620	Sulfur dioxide 0.097 Soot 0.00748 Ethylbenzene 0.00284	
13	Tomsk	620	Trichoromethane 0.00285 Toluene 0.0397 Xylene 0.0084 Manganese 0.0002	
14	Tomsk	620	Benzol 0.0407 Nitrogen dioxide 0.074 Manganese 0.0002	
15	Tomsk	620	Formaldehyde – 0,0072 Toluene – 0,065	
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