Study of Environmental Factors' Influence on the Human Health in the Case of Moscow Population

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1. Introduction

Although ambient air pollution is known to affect human, quantitative measure of the impact is quite uncertain. One of the most successful approaches to evaluate adverse health consequences caused by actual concentrations of pollutants in ambient air, is risk assessment. The quantitative values of lifetime risk units (RU) recommended by international and some national organizations are often used in assessing the health risk from different sources (chemical pollutants, radioactive exposure, electromagnetic waves etc.). Recommendations of the World Health Organisation (WHO) [1,2] and United States Environmental Protection Agency (U.S.EPA) [3] in integrated risk data base (IRIS) were taken for a basis in calculating health risks caused by chemically polluted ambient air in Russian cities. We also used well established approaches [4-7] for assessing health risks from the substances not clearly defined in terms of risk units in the mentioned recomendations. In all cases, expert values of risks have been averaged, and the uncertainty range reflects the differences in the risk recommendations and the inaccuracies in methods used for measuring air pollutants.

2. Assessments Of Health Risks Caused By Chemically Contaminated Air In Moscow

Knowing the pollution levels in ambient air and population sizes under exposure we could assess and compare the health risks from air pollutions for population of Moscow. The aim is to make clear the contribution of existing atmospheric air pollution to mortality rates. For this purpose we have:

- analysed the national (U.S.EPA), international (WHO) and other approaches to health risk assessment [1-7],
- combined their recommendations, and

- used averaged values for point assessments with uncertainty range reflecting the variance in recommendations.

Some results for Moscow population are showed in Table 1. The choice of pollutants, presented in Table 1, is determined by the Russian monitoring standards and analytical methods of air pollution control. Only about 20 substances are being constantly measured at stationary monitoring posts. For the purpose of this study, the pollutants were chosen referred to as potentially hazardous in the range of measured concentrations in urban air. Results of our calculations are presented in the third column of Table 1 in absolute numbers of deaths caused by the atmosphere pollution in Moscow. The last column of Table 1 shows the relative contribution of pollutants to the corresponding mortality rates registering for Moscow citizens.

All pollutants included in the table can be divided in two groups (classes) according to their health effects pattern:

1) Pollutants increasing the frequency of overall mortality. These are: suspended particles sulphur dioxide and nitrogen dioxide.

It should be noted that this class of pollutants also contribute to respiratory tract diseases, but this part of calculations was excluded from the paper, because of the complications in evaluating air pollution impact on morbidity in Moscow population.

2) Carcinogen pollutants increasing the incidence of specific cancer diseases: leukemia and respiratory tract cancers. These group comprises all the pollutants except referred to the first class.

In Moscow where the level of suspended particles in the air is increased (more than 150 mcg/m^3), the total number of annual deaths caused by the exposure of **suspended particles** is approximately ***3500 deaths per year, 3% overall annual mortality.***

2.1 Nitrogen dioxide and sulphur dioxide

Nitrogen dioxide and sulphur dioxide are relatively important factors in death risk. Although assessments of health risk caused by the nitrogen dioxide and sulphur dioxide have a wide range of uncertainty, they obviously play an essential part in mortality caused by the ambient air pollutions.

Relatively great contribution of nitrogen dioxide in death risk is explaned by the wide range of uncertainties in recommendations or prognoses of health risk caused by this pollutant. The real quantity of nitrogen dioxide death risk, from our point of view, is in some times less (but sooner - the same order).

Among the classical pollutants sulphur dioxide has been thoroughly investigated in terms of health consequences. No evidence of important contribution of sulphur dioxide to the death risk was found in this study. This fact can probably be explained by inaccuracy of measurements of this substance in Russia. It is obvious that methods of analitical control for sulphur dioxide currently used in Russia have to be improved. Such conclusion is proved by a comparative analysis of sulphur dioxide concentrations in big cities of other countries. They may be at least ten times high.

So, relatively small contribution to death risk of sulphur dioxide (especially in comparison with nitrogen dioxide) obviously could be explained by inaccuracy of analitical control methods have been used in Russia for this substance. This assessment is used in the following comparative analysis.

Substances	Annual risk of death, 10^{-6} [y^{-1}/mcg/m^3]	Refe rence	Averaged annual concentration [mcg/m^3]	Absolute annual health risk [deaths per year]	Relative annual health risk [%]
Suspended Particles	~4 (0.8-17)	[3-5]	100	3500	3% [1]
Nitrogen dioxide	<3	[3]	80-100	<2000*	<1.5% [1]
Sulfur dioxide	~8.4	[5,6]	*1-3***	*<200*	*0.15%* [1]
			10 ***	750	<0.5% [1]
Benzene	~0.09 (0.06-0.12)	[1,2]	*190-340***	*180*	*22-39%* [2]
			*25****	20	2.7% [2]
Benzo(a)pyrene	~660 (25 - 1300)	[1,2]	0.009	55	1.5% [3]
2.3.7.8-TCDD (Dioxin)	$4.73*10^{-5}$	[2]	$5*10^{-6} - 11*10^{-6}$ **	21 - 45	0.5% - 1.1% [4]
Formaldehyde	~0.09	[2]	3	3	0.1% [4]
Cadmium	26	[1]	0.01	2.3	0.1% [4]
Nickel	~5.3 (4.9-5.7)	[1,2]	0.01	0.5	0.02% [4]
Polychlorinated biphenyls(PCBs)	31	[2]	$(2-3)*10^{-4}$	0.1	0.002% [4]

Table 1. Assessments of health risks caused by air pollutions in Moscow city (1992-1996)

Notes: *) Upper bound. **) It is necessary to elaborate the methods of measuring. ***) Expert assessment

Risk values are given relatively annual mortality intensitives (Moscow, 1994):

1) all causes; 2) leukemia; 3) lung, trachea, bronhial cancers; 4) respiratory tract cancers.

2.2 Carcinogenic pollutants

Carcinogenic pollutants (second class): Arsenic, Cadmium, Vinylchloride, Nickel, Benzene, Benzo(a)pyrene, Dioxin (Moscow), Formaldehyde. The contribution of these substances to the mortality from cancer diseases varies from 1 to 3 %.

For Moscow, carcinogenic air pollutants can be divided in two subgroups according their potencial hazards:

a) relatively hazard: Benzene, Benzo(a)pyrene, 2.3.7.8 - TCDD (Dioxin). The contribution of these substances to the cancer mortality equals to 1%-3% of registrated existing levels of frequency.

2.2.1 Benzene problem for Moscow?!

It is necessary to say a few words about the hazard from Benzene pollution. We found extremly high relative hazard (about 25% of leukemia frequency) level of this pollutant for Moscow population. The Benzene problem can be really actual, if the official data (that must be used) of Benzene concentration in atmospheric air of Moscow are correct. Comparisons with other data of Benzene concentration in air of Russian cities lead us to the conclusion, that the concentration of Benzene in Moscow atmospheric air is overestimated. That's why we put in the Table 1 our expert judge (marked by three stars) about the supposed real level of Benzene concentration, which is one order less. Anyway, it gives relatively high contribution of Benzene to health risk.

It is necessary to continue anlysis of health risks caused by air pollutions of Benzene, Benzo(a)pyrene, 2.3.7.8 - TCDD (Dioxin) in Moscow city.

b) potencial hazard of the other investigated carcinogenic pollutants: Formaldehyde, Cadmium, Nickel, Polychlorinated biphenyls (PCBs) ***is negligible*** (less than 0.1%).

2.3.Preliminary conclusion

Analysis of all presented rezults show the main role of noncarcinogenic pollutants. From our view, the contribution of noncarcinogenic pollutants to all deaths caused by air contamination is far beyond 50%, reaching the 90%. The total contribution of carcinogenic pollutants to all deaths caused by air pollution is less than 10%. The contribution of pollutants studied elsewhere to deaths caused by air contamination can be varied from 10% to about 40%. Further researches are necessary.

3. Assessments of Health Risks Caused by Chemically Contaminated Drinking Water in Moscow

The familiar estimations have been made for death risks, caused by chemically contaminated drinking water. We made this analysis for Moscow population, using the data of the official report on Moscow environmental contamination in 1992. We have faced with great problems searching the published data. They are very few and usially unbelivable. That is why the correctness of our estimations can be questionable. Anyway, we tried to understand the orders of death risks on the basis of data published.

We assessed the orders of death risks caused by the pollution levels of carcinogenic substances, controlled in Moscow drinking water. The basical method for estimation - the U.S.EPA approach [2]. The results of our assessment are presented in Table 2.

Substances	Annual risk of death, 10^{-6} [y^{-1}/mcg/l]	Averaged annual concentration [mcg/l]	Absolute annual health risk [deaths per year]	Relative annual health risk [%]
Chloroform and Trichlorethylene	0.018 - 0.19	~30-100 (3.0 - 280)	~30-90 (0.5 - 500)	~<1% [1)]
Arsenic	~0.8	2-5 (0.1 - 10)	15-35 (7 - 70)	0.2-0.4% [1)]
Carbon tetrachloride	~0.2	0.4-2 (0.3 - 4.8)	1-3 (<8)	0.01-0.04% [1)]
Benzo(a)pyrene	~3	0.01-0.03 (0.001 - 1.0)	0.3-1.0 (<30)	negligible 0.2-0.4% [1)]
Beryllium	1.8	0.02-0.05	<0.8	negligible

Table 2. Assessments of health risks caused by drinking water pollutions in Moscow city

Notes: Risk values are given relatively annual mortality intensitives (Moscow, 1994): 1) perroral tract cancers.

For Moscow, carcinogenic drinking water pollutants can be divided in two subgroups according their potencial hazards:
a) relatively hazard: Chloroform and Trichlorethylene, Arsenic, Carbon tetrachloride. The contribution of these substances to the perroral tract cancer mortality is less than 1%.
b) potencial hazard of Beryllium and Benzo(a)pyrene ***is negligible.***

4. Comparative Analysis of Death Risk Orders

The aim of this stage of our study was to compare death risks caused by air and drinking water pollutions in Moscow city and to make a comparative analysis with other kinds of risks for better understanding of the hazards posed by environmental pollutions (Fig.1).

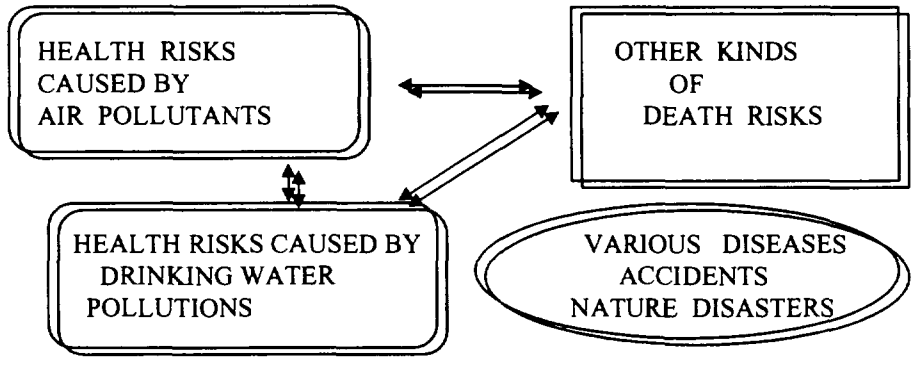

Figure 1. The scheme of comparative death risk analysis

The comparisons of mean death risks caused by air and drinking water pollutions in Moscow city are presented in Table 3. Relative contributions to death risk shows the main hazardous carcinogenic substances. They are ranking the following:

Chloroform and Trichlorethylene (water), Benzo(a)pyrene (air), Arsenic (water), Dioxin (air), Benzene (air). Their relative contributions to the total death risk of contaminated environment varies from 10% to 30%.

Carcinogenic substances	Air pollution	Drinking water pollution	Absolute annual health risk [deaths per year]	Relative contribution to introduced annual health risk, [%]
Chloroform and Trichlorethylene		+	~60	30
Benzo(a)pyrene	+	+	56 (55/0.6)	28
2.3.7.8-TCDD(Dioxin)	+		~28	14
Arsenic	?	+	~25	13
Benzene	+		~20	10
Formaldehyde	+		3	2
Cadmium	+	+	2.3 (2.3/0)	1
Carbon tetrachloride		+	~2	1
Beryllium		+	0.8	<0.5
Nickel	+	+	0.5 (0.5/0)	<0.5
Polychlorinated biphenyls(PCBs)	+		0.1	0.00
		Total	~200	100

Table 3. Carcinogenic health risks caused by air and drinking water pollutions in Moscow city (1992-1996)

Carcinogenic substances	Air pollution	Drinking water pollution	Upper bounds of estima-tions of annual health risk [deaths per year]	Relative contribution to introduced annual health risk, [%]
Chloroform and Trichlorethylene		+	<500	50.8
Benzene	+		<270	27.4
Benzo(a)pyrene	+	+	<85	8.6
Arsenic	?	+	<70	7.5
2.3.7.8-TCDD(Dioxin)	+		<45	4.1
Carbon tetrachloride		+	<8	0.8
Formaldehyde	+		3	0.3
Cadmium	+	+	2.3	0.2
Nickel	+	+	<1	0.1
Beryllium		+	0.8	<0.1
Polychlorinated biphenyls(PCBs)	+		0.1	0.00
		Total	~985	100

Table 4. Upper bound estimations of carcinogenic health risks caused by air and drinking water pollutions in Moscow city (1992-1996)

The same kind of comparisons, but of upper bound death risks caused by air and drinking water pollutions in Moscow city are presented in Table 4. Of course, the relative contributions to death risk shows the same list of main hazardous carcinogenic substances. Their relative contributions to the total death risk of contaminated environment varies from 4% to 50%. And there are some changes in their ranking: Chloroform and Trichlorethylene (water), Benzene (air), Benzo(a)pyrene (air), Arsenic (water), Dioxin (air). Benzene takes the second place in this case, moving from the end of the list.

If we compare (Fig. 2) the total value of upper bound carcinogenic death risk estimation with the noncarcinogenic death risk caused by suspended particles, we can see, that the upper bound carcinogenic risk is only about 20% of total mortality caused by the air pollution of suspended particles.

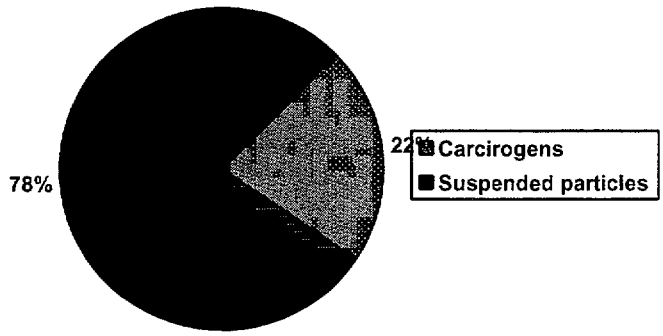

Figure 2. The total value of upper bound carcinogenic death risk estimation in comparison with the noncarcinogenic death risk caused by suspended particles (the Moscow city).

A rough scale guide of annual risk orders								
L o w			M i d d l e			H i g h		
Neglec-tive		relative-ly low		relative-ly high		vital	Extreme	
<	10^{-8}	10^{-7}	10^{-6}	10^{-5}	10^{-4}	10^{-3}	10^{-2}	>
A rough guide for hazard scale								
8	7	6	5	4	3	2	1	

Figure 3. Classification of death risk orders for population

To make a comparative analysis with other kinds of risks for better understanding of the hazards posed by environmental pollutions, we used a rough scale of risk orders (Fig.3).

Introduction of order hazard scale faciliates:

- the comparisons of quite uncertain health risk assessments;
- the process of decision making on the stage of risk management.

Basing upon this scale of fatal risk orders for population we have made a comparative analysis of fatal risk orders from air and drinking water pollutants versus main causes of death and natural hazards. The results are presented in Table 5. And Table 6 presents the comparisons of health risks from air pollutions in Russian cities with other kinds of risks, i.e. health risks from drinking water pollutions in Moscow, a major group of fatal diseases and natural disasters.

We may conclude that:

1) Environmental pollutions do not produce the death risks in the HIGH hazard range.
2) The most hazardous air and drinking water pollutants produce death risks in the MIDDLE hazard range. The death risks of:

- air pollution (defined through suspended particles) equivalent to the death risks from such disease as Chronic bronchities, Suicides, Murders, All accidents or Transport accidents;
- Nitrogen dioxide is close to death risks due to Diabetes, Chronic alcogolism and alcoholic psychosis, All accidents except transport, Falls, Drawned;
- Sulphur dioxide (Moscow) and Arsenic are copmared with death risk due to Fires;
- Vinylchloride and Cadmium can be compared with nature disaster risks;
- air pollutions of Benzene, Nickel, Benzo(a)pyrene, Dioxins are equivalent to drinking water pollutions of Arsenic, Chloroform and Trichlorethylene, and all they comparable with such natural risks as flood, tsunami, earthquakes, typhoons, cyclones or storms.

3) The less hazardous air and drinking water pollutants produce death risks in the LOW hazard range. The death risks of:

- air pollutions of Formaldehyde and Cadmium (Moscow) are equivalent to drinking water pollution of Carbon tetrachloride, and they comparable with Thunder storm natural risk;
- air pollution of Nickel (Moscow) are equivalent to drinking water pollution of Beryllium and Benzo(a)pyrene, and to Hurricane and Tornado natural risks.

Health hazards	*Range of annual death risk*						
	< 10^{-7}	*10^{-6}*	*10^{-5}*	*10^{-4}*	*10^{-3}*	*10^{-2}>*	
Ambient air pollutions:							
Suspended particles				I----	---- **-	I	
Nitrogen dioxide				I--**-	I		
Sulphur dioxide (Moscow)			I	----*-I			
Arsenic				*			
Cadmium				*			
Vinylchloride			I--	*--I			
Nickel			*				
Benzene			I---- *-	---I			
Benzo(a)pyrene		I-----	--- *-*I				
Dioxin (Moscow)			*				
Formaldehyde		I*--*I					
Cadmium (Moscow)		*					
Nickel (Moscow)	**						
Drinking water pollutions:							
Chloroform and Trichlorethylene		I-----	---- ***	----I			
Arsenic		I	- *** --I				
Carbon tetrachloride	I-	****- -I					
Beryllium	**						
Benzo(a)pyrene	--***	---I					
Fatal diseases:							x
Heart diseases						x	
Cancer diseases						Xx	
Marrow vessels diseases					x	X	
Chronic bronchities					x		
Diabetes					x		
Chronic alcogolism and alcoholic psychosis				x	x		
Suicides					x		
Murders					x		
Accidents:					xxx		
Automototransport					xx		
Falls				x			
Drawned				x			
Fires				x			
Others				x	x		
Nature disasters:			O	O			
Flood, tsunami			O				
Earthquake			O				
Typhoon,cyclone,storm			O				
Thunder storms		O					
Hurricane, tornado	O						

Table 5. Comparative analysis of population death risk orders

Hazard	Fatal diseases, accidents etc.	Air pollutants	Drinking water pollutants	Nature hazards
H	All diseases			
I G	Heart diseases Cancer diseases			
H	Marrow vessels diseases			
	Chronic bronchities Suicides	Suspended particles		
M	Murders All accidents Transport accidents			
I	Diabetes Chronic alcogolism and alcoholic psychosis	Nitrogen dioxide		
D	All accidents, except Transport Falls, Drawned			
D	Fires	Sulphur dioxide (Moscow) Arsenic		
L		Cadmium Vinylchloride		Nature disasters
E		Benzene Nickel Benzo(a)pyrene Dioxins (Moscow)	Chloroform and Trichlorethylene Arsenic	Flood, tsunami, Earthquake, storm, typhoon, cyclone
L O		Formaldehyde Cadmium (Moscow)	Carbon tetrachloride	Thunder storms
W		Nickel (Moscow)	Beryllium Benzo(a)pyrene	Hurricane, tornado

Table 6. Comparative analysis of various death risks using the hazard scale

5. General Conclusion

The risk assessments and comparative risk analysis provide evidence of the health hazards for the urban population in Russia associated with increased levels in air of such noncarcenogenic pollutans (reviewed in this study) as Suspended particles, Nitrogen dioxide, Sulphur dioxide; carcinogenic air pollutants, as Benzene, Vinylchloride, Arsenic, Cadmium, Nickel, Benzo(a)pyrene and Dioxins;

carcinogenic water pollutants, as Chloroform and Trichlorethylene, Arsenic. Futher investigation is required including both the analysis of health risks from other pollutants and elaboration of the presented results.

References

1. Air Quality Guidelines for Europe. WHO (1987). Regional Publications, European Series, No 23.
2. Rolaf van Leeuwen F.X. (1997). WHO Air Quality Guidelines for Europe. European EpiMarker, April 1997.
3. U.S.Environmental Protection Agency (1995). Integrated Risk Information System - IRIS.
4. Introduction To Cost-Effectiveness Analysis Of Risk Reduction Measures In Energy Systems. (1986). IAEA-TECDOC-383, Vienna.
5. R.Mendelson (1980) An economic analysis of air pollution control from coal-fired power plants, Journal of Environmental Economics and Management, vol.7.
6. Hamilton L.H. (1979) Health effects of electricity generation. Presented at the conference on health effects of energy production, sponsored by Chalk River Nuclear Laboratories, Ontario, Canada, 1979.
7. Bykov A.A., Murzin N.V. (1997). The Problems Of Individual, Societial and Environmental Safety Analysis. Nauka, St.-Petersburg. (in Russsian)