Assessment of human health risk caused by chemical pollutants of the atmosphere

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Based on the data of Tomsk Hydrometeorology and Environmental Monitoring Center, the diurnally mean, annually mean, and maximal concentrations of main substances polluting atmospheric air of Tomsk for 1993–2002 were calculated and the cancer risk was assessed using the "RISK ASSISTANT" software and normative documents of the State Committee for Sanitary and Epidemiological Oversight under the Russian Ministry of Public Health. Territories with minimal, maximal, and medial level of the cancer risk are identified.

Chemical pollution of environment is dangerous for human health. This problem is extensively studied in order to determine quantitatively the degree of the danger influence on the human organism.

Assessment of human health risks connected with the environmental pollution is presently one of the most important medical-ecological tasks.[1,2]

In scientific sense, the risk assessment requires a successive and systematic consideration of all aspects of the effect of the factor under analysis on the human health and substantiation of its permitted level.

The purpose of this paper is to assess the carcinogenic risk for the human health provoked by the atmospheric air pollution in Tomsk, which, like the pollution of drinking water and soil, is an unfavorable environmental factor.[3] For the first time, this risk for Tomsk was estimated in accordance with stated normative documents.

The state of atmospheric air in Tomsk is determined by emissions of pollutants from stationary and nonstationary sources.[4] Enterprises and motor vehicles eject more than 250 pollutants to the atmospheric air. There are 5.5 thousand stationary sources of the atmospheric pollution in Tomsk belonging to 194 industrial enterprises. Main polluters are power stations (21.5%), mechanical engineering and metal-working plants (18%), as well as fuel (17.4%), food (9.7%), chemical, and petrochemical (7%) plants.

The share of motor vehicle emission in total emission in the city makes about 78% (77.9 thousand tons per year). Causes of the determined degree of the pollution are the high traffic, the increased content of pollutants in exhausts, and a poor quality of the roadway cover.[5]

Main attention in our work was devoted to air measurements,[6] regularly conducted by the hydrometeorological service of the city at stationary observation sites (OS), which allow obtaining a confident information on the actual pollution of the atmospheric air throughout the city territory. Based on these data, we calculated diurnally mean, annually mean, and maximal concentrations of main air pollutants in 1993–2002.

Assessment of carcinogenic risk was made in accordance with normative documents of the State Committee for Sanitary and Epidemiological Oversight under the Russian Ministry of Public Health,[7] using the approach of the US Environmental Protection Agency (US EPA),[8] officially accepted in the Russian Federation and recommended by the World Health Organization and the UN Environmental Program, using the "RISK ASSISTANT" software.[9] We considered only adverse substances received by the organism through respiratory tract (inhalation exposition). We have chosen a group of people suffered hazardous impacts. In this work, we deal with "an average inhabitant," who has the following parameters: 70 years old, a weight of 70 kg, and a 30-year exposition. It is assumed that Tomsk is his permanent residence, and he is exposed to the hazardous impacts for 3 h per week.

The carcinogenic risk is calculated by the formula

$$CR = 1 - \exp(-SF \cdot LADD),$$

where CR is the individual carcinogenic risk; LADD is the diurnally mean dose during the life, mg/(kg · day); SF is the factor of the carcinogenic potential $[mg/(kg \cdot day)]^{-1}$ (the Program uses the database of carcinogenic properties of substances http://www.epa.gov/iris/subst/).

These assessments represent the theoretical additional *carcinogenic risk* (i.e., risk in excess of the background morbidity). For instance, if the calculated risk is 1/1000 000, then the chance of a person to fall ill with cancer due to particular chemical impact in addition to his chances to fall ill with cancer for other reasons is 1/1000 000.

The cancer risk was assessed for all substances whose concentrations are constantly measured at OSs: the dust, sulfur oxide (IV), nitrogen oxide (IV), carbon oxide (II), hydrogen sulfide, phenol, formaldehyde,

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ammonium, and hydrogen chloride. The cancer risk is calculated for every pollutant individually.[7–9] Individual cancer risks due to all these substances, excepting the formaldehyde, are less than $1 \cdot 10^{-6}$. Based on classification of risk levels,[7–9] the individual risk equal or less than $1 \cdot 10^{-6}$ throughout the life corresponds to one additional case of a serious disease or the death per one million of exposed individuals; it characterizes such risk levels, which are considered by people as negligibly small and not differing from usual, everyday ones. These risks require no extra measures toward their reduction, and their levels are controlled only periodically.

Thus, the individual cancer risk due to the atmospheric air inspiration by inhabitants of Tomsk is provoked by the formaldehyde. Analysis of observation data has shown that the formaldehyde concentration in air for the observation period several times exceeded the diurnally mean maximum permissible concentration by a factor of 4–6.

Formaldehyde HCHO is a colorless gas with a pungent odor, belonging to the widespread pollutants connected with chemical and metallurgical plants, with production and the use of carbamide resins (the production of polymers, construction materials, furniture, etc.), as well as exhausts of automobile engines. In homes, the source of dangerous formaldehyde concentrations may be the new furniture, construction materials on the basis of carbamide resins, facing of walls and ceilings, wallpaper, etc. The available approximate estimates suggest that from 2.5–3 to 5–6 thousand tons of formaldehyde income every year to the air basin of Russian towns. In most cases, its concentration is within 3–12 μg/m^3 (at a diurnally mean maximum permissible concentration of 3 μg/m^3). There are its increased (up to 100–280 μg/m^3) concentrations in the air of a number of towns (Volgograd, Kemerovo, Krasnoyarsk, Norilsk, Omsk, Tolyatti, Usolye-Sibirskoe, etc.). Substantially increased (up to 100 μg/m^3) HCHO concentration is typical for the air of rooms, where the intense smoking takes place. Formaldehyde makes toxic, mutagenic, allergenic, and carcinogenic effect on people, mainly, through inspiratory channel. The amount of the daily inhaled compound is about 1, rarer 2 mg. The smoking is an additional source. Delivery with water is negligibly small. The symptoms of the short-term impact are the irritation of eyes and mucous membranes of nose, larynx, as well as the lacrymation, cough, dyspnea, and nausea.

Variations of the individual carcinogenic risk at OS of Tomsk in period 1993–2002 is shown in Fig. 1.

Maxima of the individual carcinogenic risk, observed at OS-2, OS-14, and OS-13, fall within period 1999–2000 and are associated not with the growth of the total emission of gaseous substances into the atmosphere, but rather with the increasing volume fraction of the formaldehyde.

According to data for 2002 (see Table), the minimal risk level was observed at OS-11 (crossroad of Proletarskaya street and Baranchukovskii lane), OS-5 (Gertzen street, 68), OS-13 (Vershinin street), and OS-14 (Lazo street).

In accordance with the risk classification, such a risk is characterized as low. The individual risk throughout the life is approximately between $1 \cdot 10^{-4}$ and $1 \cdot 10^{-6}$, which corresponds to a zone of the conventionally acceptable (permissible) risk; just this level corresponds to most foreign standards recommended by international organizations for population as a whole.

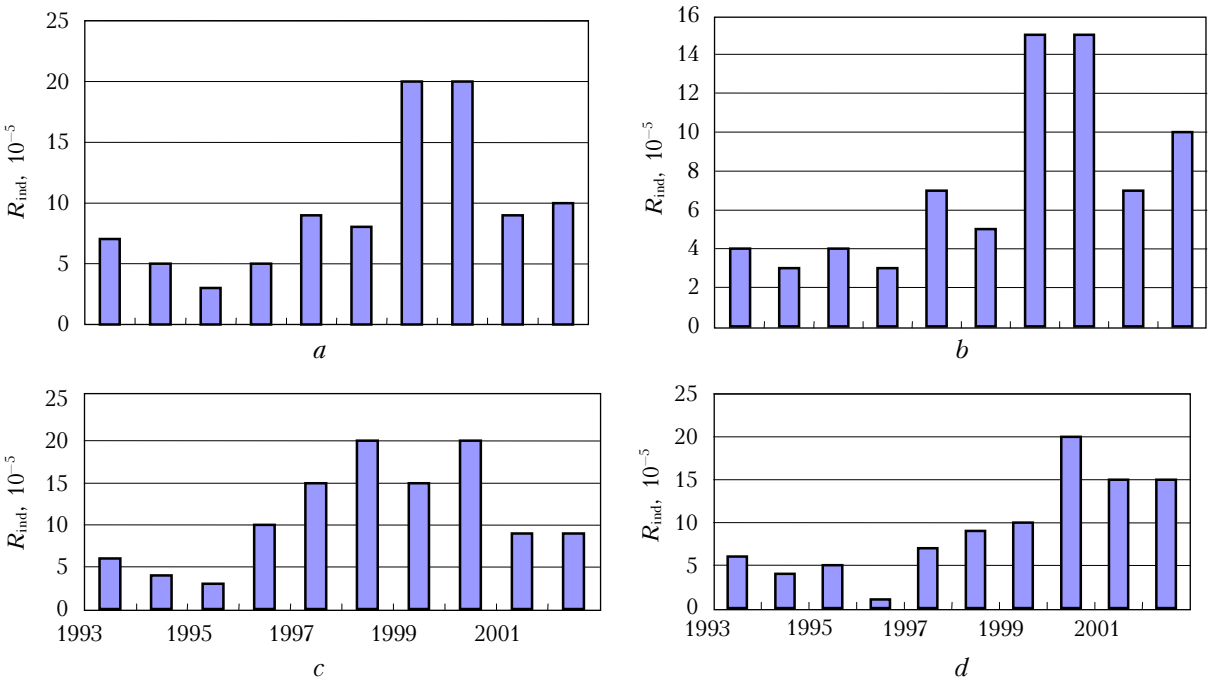

Fig. 1. Change of the individual carcinogenic risk at OSs: (*a*) OS-11; (*b*) OS-13; (*c*) OS-14; and (*d*) OS-2.

Ranking of individual carcinogenic risk levels for 2002

No. of site	Address	Individual lifelong carcinogenic risk	Risk level
OS-2	Lenin square	$2 \cdot 10^{-4}$	medium
OS-5	68, Gertzen street	$8 \cdot 10^{-5}$	low
OS-11	crossroad of Proletarskaya street and Baranchukovskii lane	$1 \cdot 10^{-4}$	low
OS-12	Svetly village	$2 \cdot 10^{-4}$	medium
OS-13	Vershinin street	$1 \cdot 10^{-4}$	low
OS-14	Lazo street	$9 \cdot 10^{-5}$	low

The maximal risk level is observed at OS-2 (Lenin avenue) and OS-12 (Svetly village), where it is characterized as medium; this level of the risk requires making special sanitary measures.

The confident average risk over the city territory is $7.7 \cdot 10^{-5}$. This means that during 70 years there is a possibility of occurrence of seven additional cancer cases in population of 100 000 people experienced the inhalation formaldehyde effect.

The results of the study show that the obtained value of the individual risk equal to $2 \cdot 10^{-4}$ admits a probability of occurring two additional cancer cases during 70 years in population of 10 000 people exposed to the inhalation effect of formaldehyde. Such a risk is observed in the center of the city at Lenin avenue and in Svetly village. In accordance with the classification, such individual lifelong carcinogenic risk has a medium level and is unacceptable for population as a whole. The appearance of such risk requires the elaboration and making of planned sanitary measures.

Low risk levels of $8 \cdot 10^{-5}$ and $9 \cdot 10^{-5}$ are observed in Gertzen street and Lazo street, respectively; and they are considered as minimal.

The analogous work was performed for Saint Petersburg.[1] The obtained results show that the values of the carcinogenic risk for 20 regions are between $4.9 \cdot 10^{-5}$ and $11.2 \cdot 10^{-5}$. This approximately corresponds to the data of our work for Tomsk. Seemingly, such a risk level may characterize urbanized territories with a heavy anthropogenic load. It is important to note that the formaldehyde is also the only substance contributing to the total risk. Calculations were performed for 12 primary pollutants using data of stationary sites of observation for the atmospheric air state in Saint Petersburg.

Thus, the assessment of the carcinogenic risk allows one to predict possible consequences for human health from the comparison of qualitative risk levels for a long observation period for different scenarios of development of the industrial production, automobile transport, and economic activity as a whole.

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