

Atmospheric Air Pollution by Anthropogenic Objects and Impact of Its Quality on the Environment and Human Health



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1 Introduction

The level of urbanization of the territory is increasing every year, the number of man-made facilities is growing and human production and economic activity is intensifying. This is the reason for an increase in the concentration of anthropogenic pollutants in the atmosphere, which results in the change of the environment quality and affects human health [1, 2].

The growth of industrial production in the Penza region results in the fact that significant amounts of pollutants of various origin are released into the air every day (sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), suspended solids (SS), benzene (C_6H_6), toluene (C_7H_8), formaldehyde (CH_2O), etc.), affecting environmental objects and the functional state of the human body [3, 4]. The accumulation of these substances in environmental objects will eventually result in the accumulation of quantities significantly exceeding safe levels (MAC), and will cause irreversible consequences. For example, an increase in the concentration of sulfur and nitrogen oxides and their combination with water vapor in the atmosphere can cause acid rains which acidify the soil and reservoirs, changing the characteristics of the habitat of the flora and fauna in the area. Similarly, the substances released into the atmosphere can settle on the soils, penetrate into them and destroy their structure and properties. A human reaction to pollutants in the environment depends on one's gender, age, health and place of residence relative to the object of production and economic activity. The presence of these pollutants in the air of a residential area can cause the occurrence and/or increase in the cases of allergic, respiratory, cardiovascular, oncological, and nervous system diseases [5–18].

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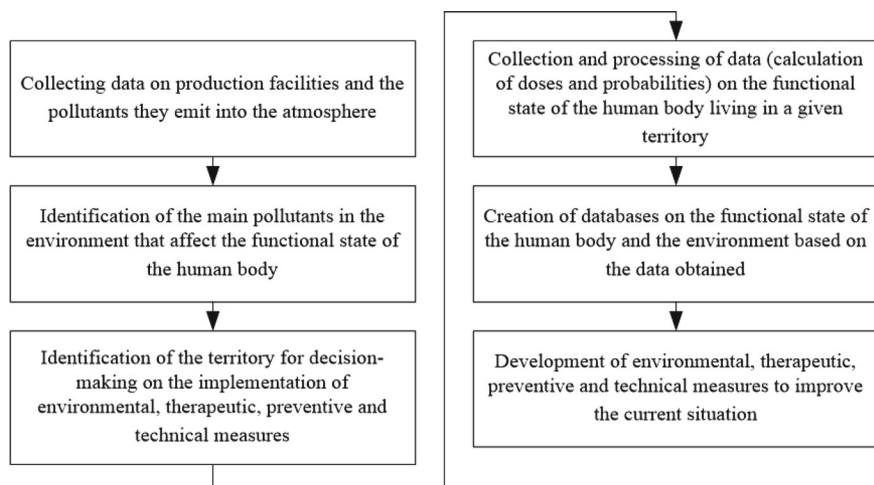


Fig. 1 An algorithm for monitoring the environment and human body functional state

Constant residence in the vicinity of the objects of industrial and economic activity is the cause of the burden of diseases, namely, deterioration of the functional state of the human body, an overall increase in morbidity, a decrease in life expectancy and an increase in mortality [19].

To control the qualitative and quantitative characteristics of emissions from industrial and economic facilities and the city of Penza, as well as their impact on the quality of the habitat and the functional state of the human body, an algorithm is proposed, shown in Fig. 1 [20–22].

This approach will help to conduct qualitative control on human industrial and economic activities, the state of the environment and the functional state of the human body.

The main **purpose** of this study is to define the impact negative factors of industrial and economic activity in the city of Penza, generated by industrial enterprises located in the “manufacturing” district of the city, have on the state of the environment and the functional state of the human body.

To do this, we are to solve the following **objectives**:

- analyze the production and economic activity in the city of Penza and identify the most significant pollutants;
- determine the number of pollutants released into the environment during production and economic activities and affecting the functional state of the human body;
- determine the probability of a change in the functional state of the human body under the impact of these pollutants.

2 Theory

Anthropogenic objects are the sources of possible negative effects on the environment and the functional state of the human body. To define the impact of emissions on the state of the environment and the functional state of a human body, there is a set of regulatory documents [22, 23]. Based on them, a methodology has been developed to determine the probability of changes in the functional state of the human body when exposed to pollutants through the atmosphere.

According to [22, 23], the number of pollutants in the atmosphere during the observation period is determined by the formula:

$$A_{av} = A \cdot t \quad (1)$$

where A_{av} is the average daily dose (ADD) of pollutants, averaged to account for chronic exposure (mg/kg per day); A is the average daily dose of pollutants on the day of exposure (mg/kg per day); t is a coefficient that takes into account the time of exposure of a pollutant to a person and is defined by the formula:

$$t = \frac{E}{D} \quad (2)$$

where E is the period of exposure of the pollutant to the environment and the functional state of the human body (day); D is the number of days per year.

The calculation of the ADD of pollutants entering the environment and, accordingly, into the human body is done according to the formula:

$$A = \frac{c \cdot R \cdot E}{m \cdot T} \quad (3)$$

where c is the concentration of a pollutant in the atmosphere (mg/m³); R is the rate of entry of an air stream containing pollutants into the atmosphere (m³/day); m is the human body weight (kg); T is the exposure averaging period (day).

The collection of initial data to define the probability of a change in the functional state of the human body under the impact of the pollutants under study begins with defining the size of the impact zone at the object of production and economic activity. The impact zone consists of two parts: the first part is a sanitary protection zone of an industrial and economic activity facility, the second is a potentially dangerous zone of negative factors' impact equal to it in size.

Further, samples are made from the population living inside and outside the zone of exposure to the studied pollutants, and the effect of the ADD of each pollutant considered on each person in the sample is determined. For this purpose, a number of medical, laboratory and diagnostic studies are conducted for each person from the sample to identify possible deviations under the influence of the studied pollutants, as well as combining them into special databases. Based on the information received,

the ratio between the disfunction in the state of the human body and the presence of pollutants in the environment is established.

Judging by the data obtained on the disorders in the human body, it is classified into the appropriate class of diseases (DC) for each person in the sample, depending on the location inside or outside the zone of exposure to the pollutants considered.

After that, the values of the chronic total cardiovascular disease and the corresponding class of diseases are correlated for each person in the sample, depending on whether they are inside or outside of the affected area.

Based on the information received, databases are supplemented for each person in the sample.

After that, for each person in the sample, the chronic total ADD of each pollutant is calculated, which causes some functional disorder according to the formula:

$$D_i^Z = \frac{1}{N} \sum_{j=1}^N A_{avj}^i \quad (4)$$

where D_i^Z —is the chronic total ADD of pollutants causing a separate newly identified chronic disease that is part of a specific DC for all individuals with this disease, for all control points for the conditions of the annual averaging period, mg/(kg per day); A_{avj}^i —chronic ADD of pollutants defining a newly diagnosed chronic disease included in a certain DC for all persons with this disease at each control point for the conditions of the annual averaging period in the affected area, mg/(kg per day); N is the number of people with a newly diagnosed chronic disease included in a certain DC relative to the period of observation preceding the assessment moment.

For people outside the affected area, the chronic total ADD of each pollutant is calculated using the formula:

$$\overline{D_i^Z} = \frac{1}{N} \sum_{j=1}^N \overline{A_{avj}^i} \quad (5)$$

where $\overline{D_i^Z}$ —is the chronic total ADD of pollutants not associated with a negative response, mg/(kg per day); $\overline{A_{avj}^i}$ —chronic ADD of pollutants, which determines a newly diagnosed chronic disease included in a certain DC, for all persons with this disease at each control point for the conditions of the annual averaging period outside the exposure zone, mg/(kg per day); N is the number of people with a newly diagnosed chronic disease included in a certain DC relative to the observation period preceding the moment of assessment.

Then, the calculation of the chronic total ADD is done for each pollutant causing a health disorder in the form of newly identified chronic diseases in general over the entire spectrum of identified disease classes in the affected area using the formula:

$$D_i^K = \frac{1}{K} \sum_{j=1}^K D_i^Z \quad (6)$$

where D_i^K is the chronic total ADD of the pollutant which forms a newly identified chronic disease as a whole over the entire spectrum of detected disease classes, for the corresponding observation period, mg/(kg day); D_i^Z is the chronic total ADD of the pollutant, which defines a newly identified chronic disease included in a certain DC, at all control points for the corresponding observation period (1 year), mg/(kg per day); Q is the number (quantity) of detected DC during the corresponding observation period (1 year).

For people outside the affected area, the chronic total ADD of the pollutant is calculated using the formula:

$$\overline{D_i^K} = \frac{1}{K} \sum_{j=1}^K \overline{D_i^Z} \quad (7)$$

where $\overline{D_i^K}$ is the chronic total ADD of pollutants which forms a newly diagnosed chronic disease in general over the entire spectrum of detected disease classes not associated with a negative response, mg/(kg day); $\overline{D_i^Z}$ is the chronic total ADD of pollutants not associated with a negative response, mg/(kg day); Q is the number (quantity) of detected DC per the corresponding follow-up period (1 year).

Based on these calculations, as well as the data on production facilities that affect the atmosphere, it is possible to identify the impact of each studied pollutant on the occurrence of disease in the population of a given territory and justify the need to reduce pollutant emissions [22].

To conduct this study, special software was used [24], which implements the methodology [22] and facilitates calculations.

3 Practice

According to sanitary and hygienic monitoring data, the most common pollutants released into the atmosphere of Penza by industrial enterprises are SO_2 , NO_2 , BB, CO and CH_2O . The study uses the results of monitoring of industrial facilities located within the city of Penza and surrounded by a residential area.

The distribution zone of the pollutants under study is defined by a distance of 2 km from the objects of industrial and economic activity, of which 600 m near the objects are the affected area where the population has a greater contact with the studied pollutants. The height of the discharge sources of industrial and economic objects is 50 m. The planned annual emissions reduction is 15%. The average annual wind speed is 9 km/h, the wind is mainly westerly.

Table 1 Maximum permissible concentrations of the studied pollutants

Parameter	SO ₂	NO ₂	BB	CO	CH ₂ O
MPC, mg/m ³	0.05	0.04	0.075	3.0	0.003

Due to the predominant westerly wind, people living in the area in the direction of the wind flow and located at the required distance from the industrial facility were identified in the sample. The entire population of the studied area of the city is divided into 14 groups according to age and weight characteristics. At the first stage of the study, one representative was selected for each group, the analysis of whose data allowed obtaining preliminary results and identify general research trends. According to [25], the MAC for the studied pollutants are provided in Table 1.

The initial data included the weight and age of the person, as well as the measured dose of the average annual concentration of pollutants according to sanitary and hygienic monitoring data (Table 2).

Special software was used for the calculation [24]. According to the initial data (Table 2) the chronic ADD of the pollutant averaged per year were calculated, and possible classes of diseases were determined for each person from the sample inside and outside of the affected area (Table 3).

Based on the calculation results, the impact of each of the studied pollutants on the change in the functional state of the human body was determined. The results of the calculation and analysis are shown as a diagram in Fig. 2.

Thus, based on the data obtained as a result of sanitary and hygienic monitoring, it can be seen that the concentration of the studied pollutants in the affected area is greater than outside of it. Out of the study sample the people from the highest risk zone include also children and the elderly ones. The calculation results show that the pollutants studied have a negative impact on the functional state of the human body.

4 Conclusions

Based on the data obtained during the study, it should be noted that an increase in the range, quantity and concentrations of pollutants emitted in the atmosphere as a result of human production and economic activity negatively affects the state of the environment and the functional state of the human body. Therefore, it is necessary to develop and implement a set of environmental, therapeutic, preventive and technical measures aimed at minimizing and/or eliminating pollutants from entering the atmosphere.

Based on [22–24], an algorithm is proposed for analyzing the content of pollutants in atmospheric air and subsequently identifying their effect on the quality of the functional state of the human body.

According to the data obtained, it is clear that the indicators of the studied pollutants obtained in the affected area have a great impact on the risk of the incidence

Table 2 Sanitary and hygienic monitoring data for calculations

№	Age	Weight	The average annual concentration of pollutants in the environment, mg/m ³				
			SO ₂	NO ₂	BB	CO	CH ₂ O
In the affected area (up to two sizes of the sanitary protection zone)							
1	1	9	0.003	0.028	0.06	0.6	0.0024
2	3	18	0.01	0.03	0.065	2.4	0.0025
3	5	25	0.03	0.04	0.082	2.8	0.0029
4	9	30	0.045	0.044	0.086	3.2	0.0033
5	12	34	0.053	0.046	0.088	3.4	0.0035
6	15	33	0.043	0.043	0.085	3.1	0.0032
7	18	40	0.013	0.032	0.07	2.5	0.0026
8	30	59	0.02	0.035	0.075	2.6	0.0027
9	40	80	0.033	0.041	0.083	2.9	0.003
10	50	75	0.06	0.048	0.09	3.6	0.0096
11	55	77	0.023	0.037	0.08	2.7	0.0028
12	60	74	0.04	0.042	0.084	3	0.0031
13	65	84	0.05	0.045	0.087	3.3	0.0034
14	70	63	0.055	0.047	0.089	3.5	0.0036
Outside the impact zone (more than two sizes of the sanitary protection zone)							
1	1	9	0.0025	0.025	0.06	0.55	0.0096
2	3	18	0.0036	0.023	0.067	0.51	0.009
3	5	25	0.0047	0.023	0.062	0.65	0.0068
4	9	30	0.0032	0.028	0.07	0.6	0.0096
5	12	34	0.0041	0.018	0.072	0.68	0.0081
6	15	33	0.0038	0.033	0.065	0.52	0.0085
7	18	40	0.0033	0.027	0.07	0.63	0.0074
8	30	59	0.0021	0.03	0.075	0.66	0.0081
9	40	80	0.003	0.025	0.062	0.66	0.0095
10	50	75	0.003	0.028	0.052	0.67	0.0063
11	55	77	0.0045	0.024	0.052	0.45	0.0091
12	60	74	0.0029	0.024	0.067	0.63	0.0089
13	65	84	0.004	0.036	0.071	0.59	0.0085
14	70	63	0.0037	0.025	0.075	0.81	0.0074

of certain disease classes. Taking into account that no one lives in the area equal to the distance of the sanitary protection zone of the industrial and economic activity facility (300 m), and all the negative impact to the population is accounted to a potentially dangerous zone (the next 300 m).

Table 3 A chronic ADD of the pollutant and a DC to which the diagnosis of a newly diagnosed chronic disease is attributed, for each person inside and outside the affected area during the observed period (one year)

№	Chronic ADD of the pollutant, averaged by exposure with a frequency of 1 year, mg/(kg day)					DC according to the diagnosis of the disease
	SO ₂	NO ₂	BB	CO	CH ₂ O	
In the affected area (up to two sizes of the sanitary protection zone)						
1	0.006801	0.06348	0.1360	1.360	0.005441	RSD
2	0.01133	0.03401	0.07368	2.721	0.002834	RSD
3	0.02448	0.03264	0.06692	2.285	0.002367	RSD
4	0.03061	0.02993	0.05849	2.176	0.002244	DSD
5	0.03181	0.02761	0.05281	2.041	0.002101	RSD
6	0.02658	0.02658	0.05255	1.916	0.001978	B&HOD
7	0.006631	0.01632	0.03571	1.275	0.001326	NSD
8	0.006917	0.01210	0.02593	0.8992	0.0009338	RSD
9	0.008417	0.01045	0.02117	0.7396	0.0007652	B&HOD
10	0.01632	0.01305	0.02448	0.9794	0.002612	DSD
11	0.006095	0.009805	0.02120	0.7155	0.0007420	RSD
12	0.01102	0.01158	0.02316	0.8272	0.0008548	RSD
13	0.01214	0.01093	0.02113	0.8016	0.0008259	RSD
14	0.01781	0.01522	0.02882	1.133	0.001166	RSD
Outside the impact zone (more than two sizes of the sanitary protection zone)						
1	0.005668	0.05668	0.1360	1.247	0.02176	RSD
2	0.004081	0.02607	0.07595	0.5781	0.01020	RSD
3	0.003836	0.01877	0.05061	0.5305	0.005550	RSD
4	0.002176	0.01904	0.04761	0.4081	0.006529	DSD
5	0.002461	0.01080	0.04321	0.4081	0.004861	RSD
6	0.002349	0.02041	0.04019	0.3215	0.005255	B&HOD
7	0.001683	0.01377	0.03571	0.3213	0.003775	NSD
8	0.0007262	0.01037	0.02593	0.2282	0.002801	RSD
9	0.0007652	0.006376	0.01581	0.1683	0.002423	B&HOD
10	0.0008162	0.007618	0.01414	0.1822	0.001714	DSD
11	0.001192	0.006360	0.01378	0.1192	0.002411	RSD
12	0.0007996	0.006617	0.01847	0.1737	0.002454	RSD
13	0.0009716	0.008745	0.01724	0.1433	0.002064	NSD
14	0.001198	0.008097	0.02429	0.2623	0.002396	RSD

Note RSD—diseases of the respiratory system; DSD—diseases of the digestive system; B&HOD—blood diseases and diseases of hematopoietic organs; NSD—diseases of the nervous system

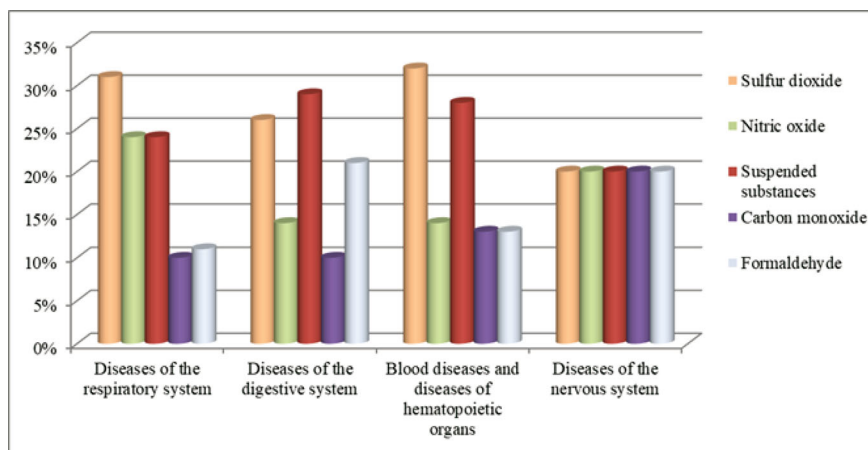


Fig. 2 The probability of a change in the functional state of the human body under the impact of the studied pollutants

The data shown in Table 3 clearly show that the probability of respiratory diseases in the population is about 57%, while the probability of other diseases is about 12–18%.

The diagram shows that the pollutants under study have various impacts on the functional state of the human body. The occurrence of respiratory diseases and diseases of blood/hematopoietic organs is mostly associated with exposure to sulfur dioxide (31% and 32%, respectively). Suspended solids are of great danger for the occurrence of diseases of the digestive system (29%). All the pollutants studied contribute equally to the likelihood of the nervous system diseases.

Of all the pollutants studied, carbon monoxide poses the least danger to the environment and the functional state of the human body, since its amount and concentration in emissions are lower than other pollutants.

Therefore, based on the obtained research data, it can be concluded that for people living in the zone of impact of anthropogenic objects, it is necessary to conduct preventive and diagnostic measures, to conduct timely control over the state of the environment where they live and over the functional state of the human body. These measures can help reduce the likelihood of diseases or completely prevent their occurrence.

Also, to reduce the occurrence of diseases in the population, it is planned to reduce emissions from the production facility by 15% per year, which will help reduce the likelihood of diseases by 1.5 times. To obtain more accurate data, the research will be continued with a more significant sample of the population living in the area considered.

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