Assessment of the impact of indicator air pollutants in Atyrau city on public health

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Abstract. The article analyzes the impact of air pollutants in Atyrau on public health, taking into account hygiene standards. Atyrau region is characterized by the development of oil and gas production and processing activities and is located on the coastal lowlands of the Caspian Sea. An oil refinery is located in the city, and as a result, atmospheric air is characterized by pollution of a number of chemical substances that are priority ones, such as hydrogen sulfide, nitrogen dioxide, formaldehyde, suspended solids, carbon monoxide, sulfur dioxide, nitrogen oxide. Most of these substances affect the respiratory system. Calculation of the inhalation risk according to the results of Kazhydromet shows that even in acute and chronic exposure, the most elevated pollutants are short-term exposure to hydrogen sulfide (HQ = 7.4), suspended particles (HQ = 4) and fine particles (HQ = 7.13) for long-term exposure. The results of field studies conducted by ECOSERVICE-S LLP show that the calculation of the risk to public health during the inhalation of pollutants is characterized by increased values under acute exposure to nitrogen (IV) dioxide (HQ = 44.03051) and hydrogen sulfide (HQ = 35, 41465). The maximum risk of acute exposure during inhalation of pollutants is formed in the area of settlement point 6 - Kursai district.

1. Introduction
The policy of intensifying production and accelerating economic development, adopted by the countries of the Caspian region, raises legitimate fears of reinforcing negative trends in the degradation of the Caspian ecosystem, which leads to environmental and social consequences.

The five coastal states are united by a common desire for sustainable management of natural resources and the conservation of biodiversity of the Caspian Sea for the benefit of present and future generations and are aware of their role and responsibility for the conservation of global biodiversity resources [1].

A variety of reserves of biological and balneological resources of the Caspian, which have no analogues in the world, reserves of hydrocarbon resources, actively developing oil and gas production predetermine the need for comprehensive environmental and social studies of the Caspian region.

The need to develop targets for the quality of the surrounding gray for the Atyrau region is due to the difficult environmental situation, formed under the influence of a complex of anthropogenic and natural-climatic factors. Among the anthropogenic factors, it is necessary to single out factors related to the activities of industrial enterprises, primarily the oil and gas and mining industries, metallurgy, food industry, and agriculture [2]. A significant share in the level of air pollution is also made by motor
vehicles, the number of which is constantly increasing. Environmental pollution associated with production and consumption waste also poses a serious risk to natural sites and public health.

In recent years, special attention has been paid to the quality of atmospheric air in Atyrau, the inhabitants of which regularly indicate this. Residents of villages in the zone of influence of oil and gas industry also make claims on the quality of the environmental situation.

Thus, the environmental situation in the Atyrau region requires measures to achieve the normative level of environmental quality indicators and prevent environmental risks to public health [2]. The solution to this problem is possible through the establishment of environmental quality targets that allow you to adjust the maximum level of normalized environmental parameters, taking into account the need and the possibility of their gradual improvement.

2. Research methods
The hazard identification stage was screening in nature and provided for the identification of all sources of environmental pollution of their possible impact on humans; identification of all pollutants; characterization of potential harmful effects of chemicals and assessment of scientific evidence of the possibility of developing these effects in humans; identification of priorities for the subsequent study of chemical compounds; establishment of harmful effects caused by priority substances during the estimated routes of exposure (including priority polluted environments and routes of entry of chemicals into the human body), duration of exposure (acute, chronic, life-long) and routes of entry into the human body (inhalation) [3].

An assessment of the impact of indicator air pollutants in Atyrau on the health status of the population was carried out taking into account the degree to which pollutants exceeded hygienic standards and the level of health risk that they posed.

As sources of information on the state of atmospheric air pollution in Atyrau, data were used on the results of monitoring of the Kazgydromet, monitoring stations of the NCOC and refineries, the results of special observations carried out within the framework of this project, and materials of summary dispersion calculations [4].

An assessment of the public health risk of pollutants contained in the air of Atyrau was carried out in accordance with the methods adopted in the Republic of Kazakhstan.

3. Results and discussion
Below are the chemicals that are priority for the conditions of air pollution in Atyrau. Atmospheric air: hydrogen sulfide, nitrogen dioxide, formaldehyde, suspended solids, carbon monoxide, sulfur dioxide, nitrogen oxide [5]. Table 1 presents the final material for the dose-response assessment phase regarding priority air pollutants in Atyrau.

Table 1. The final table of indicators of non-carcinogenic effects of substances contained in the air of Atyrau (according to stationary posts and special studies).

| Component       | Code by CAS | RfC sh. mg / m³ | RfC ch. mg / m³ | Critical organs and systems               |
|-----------------|-------------|-----------------|-----------------|------------------------------------------|
| Hydrogen sulfide| 7783-06-4   | 0.1             | 0.001           | respiratory system                        |
| Nitrogen dioxide| 10102-44-0  | 0.47            | 0.04            | respiratory system                        |
| Formaldehyde    | 50-00-0     | 0.3             | 0.003           | respiratory system, the immune system     |
| Sulphur dioxide | 7446-09-5   | 0.66            | 0.08            | respiratory system, cardiovascular system, central nervous system, blood |
| Carbon monoxide | 630-08-0    | 23              | 5               |                                                                                   |
Calculation results of inhalation risk in acute and chronic exposure to air pollutants since 2012. for the 1st half of 2018 are presented in table 2.

Table 2. Results of calculating the inhalation risk for public health in Atyrau during acute and chronic exposure to air pollutants for the period since 2012 to the first half of 2018.

| Years | H₂S HQ ch | SO₂ HQ ch | CO HQ ch | NO₂ HQ ch | CH₂O HQ ch | Suspended solids HQ ch |
|-------|------------|-----------|----------|-----------|------------|-----------------------|
| 2012  | 0.2        | 0.003     | 0.025    | 0.060     | 0.030      | n.d.                  |
| 2013  | 0.2        | 0.003     | 0.000    | 0.030     | 0.030      | n.d.                  |
| 2014  | 2          | 0.0875    | 0.070    | 2.498     | 1.250      | 0.670                 |
| 2015  | 3          | 0.830     | 0.0625   | 0.435     | 1.530      | 0.380                 |
| 2016  | 3          | 0.710     | 0.225    | 0.315     | 0.200      | 0.800                 |
| 2017  | 4          | 1.370     | 0.125    | 0.811     | 0.200      | 0.450                 |
| 2018  | 3.5        | 7.400     | 0.125    | 0.167     | 0.260      | 0.400                 |

According to the calculation results (data for the first half of 2018), the maximum acute non-carcinogenic risk is formed by inhalation of the following air pollutants - hydrogen sulfide (7.4 - high risk level), suspended solids (4 - medium risk level), fine particles PM₂.⁵ (2.19 - average risk level).

The maximum chronic non-carcinogenic risk is formed during the inhalation exposure to the following air pollutants - fine particles PM₂.⁵ (7.13 - high risk), hydrogen sulfide (3.5 - medium risk) [6].

The rest of Kazhydromet controlled air pollutants form low and minimum risk levels. The probability of a person developing critical effects with the daily intake of substances throughout life is negligible and this effect is characterized as permissible.

A slightly different assessment of the risk to public health was obtained according to the official information of the Kazhydromet system, the NCOC monitoring system and Atyrau Refinery on the level of air pollution (2017-2018). As mentioned above, the observations are carried out automatically with the conclusion of the results every 20 minutes. Access to the system data is available in authorized bodies of the Akimat of Atyrau region and the Ministry of Energy of the Republic of Kazakhstan.

According to the information provided, over the past years, an increased level of inhaled non-carcinogenic risk to public health has been periodically formed. The formation of high levels of hydrogen sulfide, which poses serious risks to public health, deserves special attention [8].

According to the information provided, levels in a number of districts of the city of Atyrau atmospheric air pollution with hydrogen sulfide can form a high level of health risk (5-10 HQ sh.) [6]. This primarily concerns the areas of Zhilgorodok, West Oil, Chagall (table 3).

Table 3. Levels of non-carcinogenic inhalation risks during chronic exposure to pollutants in the air of Atyrau according to observations of the NCOC monitoring system.

| Monitoring area | H₂S C, mg/m³ | SO₂ C, mg/m³ | NO₂ C, mg/m³ | CO C, mg/m³ |
|----------------|--------------|--------------|--------------|-------------|
| Month          | HQ ch        | HQ ch        | HQ ch        | HQ ch       |
| 2017y          |              |              |              |             |
| № 103 Chagala  | 0.0016689    | 1.6688889    | 0.0007256    | 0.0090694   |
| № 104 West Oil | 0.0131408    | 13.140833    | 0.0022192    | 0.0277396   |
The results of the calculation of non-carcinogenic inhalation risks during chronic exposure to air pollutants according to the observations of the NCOC monitoring system are presented in Table 4. According to the information provided, in 2017 and January 2018, chronic inhalation risk for public health was formed due to the content of hydrogen sulfide in the air.

Thus, the calculation of the risk of exposure to public health allows us to identify hydrogen sulfide as a priority pollutant. High and extremely high levels of risk indicate the need for the development and implementation of measures aimed at reducing it [7].

The calculation of the risk to public health during the inhalation of pollutants was based on the use of the results of calculating the maximum surface concentrations for the calculated rectangle (5776 nodes) and fixed points. Table 4 presents a list of control points at which the calculated levels of pollutants were determined.

**Table 4. List of control points for calculating maximum surface concentrations**

| №   | Point Location Address | Fixed point name | The coordinates of the posts, m (in the city coordinate system for the ERA PC) |
|-----|------------------------|------------------|--------------------------------------------------------------------------------|
| 1   | Vostok                 | Point 1          | 22270 18043                                                                 |
| 2   | Chem. Village          | Point 2          | 21216 18087                                                                 |
| 3   | Privokzalny            | Point 3          | 23048 21957                                                                 |
| 4   | S.Datov - Atambaev     | Point 4          | 19764 18531                                                                 |
| 5   | Auezov - Datov         | Point 5          | 18989 17923                                                                 |
| 6   | Kursay                 | Point 6          | 17856 15771                                                                 |
| 7   | Akimat                 | Point 7          | 19434 19947                                                                 |
Health risks were calculated for acute non-carcinogenic effects. When inhaled, the calculation of the hazard coefficient (HQ) is carried out according to the formula 1 [8]:

$$HQ_i = \frac{AC_i}{ARFC_i}, \quad (1)$$

where, HQ - hazard coefficient; ACi - maximum concentration (according to OND-86) of the i-th substance, mg/m$^3$; ARFCi - reference (safe) concentration for acute inhalation exposure for the i-th substance, mg/m$^3$.

The hazard index for the conditions of simultaneous intake of several substances by inhalation is calculated by the formula 2 [8]:

$$HI_j = \sum HQ_{ij},$$

where, HQi - hazard factors for i-x acting substances on the j-th system (organ).

With the combined intake of several substances in any way, the total hazard index is determined for substances that affect one system (organ). Table 5 presents a summary of the territory of the city where the maximum acute inhalation risk for public health is formed.

**Table 5.** Summary information on the territory of the city where the maximum acute inhalation risk for public health is formed.

| Substance                                      | Coordinates | AC, mg/m$^3$ | HQ (HI) |
|------------------------------------------------|-------------|--------------|---------|
| Point of maximum non-carcinogenic acute exposure: |             |              |         |
| X 21500                                        | Y 17500     |              |         |
| [0301] Nitrogen (IV) dioxide (Nitrogen dioxide) (4) | 20.69434    | 44.03051     |         |
| [ARFC = 0.47 mg/m$^3$]                         |             |              |         |
| [0304] Nitrogen (II) oxide (Nitric oxide) (6) mg/m$^3$ | 2.765882    | 3.841503     |         |
| [0328] Carbon (Soot, Black carbon) {RDkmr = 0.15 mg/m$^3$} | 0.364416    | 2.429441     |         |
| [0330] Sulfur dioxide (Sulfur anhydride, Sulfur gas, Sulfur (IV) oxide) (516) mg/m$^3$ | 5.673912    | 8.596836     |         |
| [0333] Hydrogen sulfide (Dihydrosulfide) (518) {ARFC = 0.1 mg/m$^3$} | 0.092618    | 0.926183     |         |
| [0337] Carbon oxide (Carbon monoxide, Carbon monoxide) (584) | 4.808681    | 0.209073     |         |
| {ARFC = 23.0 mg/m$^3$}                          |             |              |         |
| respiratory system                              | 57.39504    |              |         |
| the cardiovascular system                        | 0.209073    |              |         |
| development                                     | 0.209073    |              |         |

According to the calculation results, extremely high levels of acute risk during the inhalation route of entry are formed on the territory of the city where the industrial sites of the enterprises are located [9]. Table 6 shows the results of calculating acute non-carcinogenic risk during the inhalation route of contaminants at fixed control points.

**Table 6.** Characteristics of the non-carcinogenic risk of acute exposure during the inhalation route of contaminants.

| Substance                                      | Coordinates | HQ (HI) |
|------------------------------------------------|-------------|---------|
|                                                   |             |         |
| No. | The code | Name                                                                 | Critical organs                          | ARFC [MPCmr], mg/m$^3$ | HQ max in FP |
|-----|----------|----------------------------------------------------------------------|------------------------------------------|-------------------------|--------------|
| 1   | 0330     | Sulfur dioxide (Sulfur anhydride, Sulfur gas, Sulfur (IV) oxide) (516) | respiratory system                       | 0.66                    | 9.314015     |
| 2   | 0301     | Nitrogen (IV) Dioxide (Nitrogen Dioxide) (4)                          | respiratory system                       | 0.47                    | 3.737672     |
| 3   | 0328     | Carbon (Soot, Black Carbon) (583)                                     | not set                                  | 0.15                    | 2.698080     |
| 4   | 0333     | Hydrogen sulfide (Dihydrosulfide) (518)                               | respiratory system                       | 0.1                     | 2.144348     |
| 5   | 0304     | Nitrogen (II) oxide (Nitrogen oxide) (6)                              | respiratory system                       | 0.72                    | 0.381606     |
| 6   | 0337     | Carbon Oxide (Carbon Monoxide) (584)                                  | the cardiovascular system, development   | 23                      | 0.184193     |

Table 7 presents the ranking of air pollutants by the degree of risk to public health (by fixed control points).

Table 7. Ranking of air pollutants according to the degree of risk to public health (by reference fixed points).

If the calculated hazard coefficient (HQ) does not exceed unity, then the likelihood of a person developing harmful effects with a daily intake of a substance throughout his life is not significant and this effect is characterized as permissible. If HQ is greater than unity, then the probability of developing...
harmful effects is significant, and increases in proportion to HQ. The total hazard index (HI), which characterizes the allowable intake, should also not exceed one.

According to the calculations, air pollution in Atyrau with harmful substances emitted by stationary sources of selected industrial enterprises can form a high level of risk (sulfur dioxide), respiratory organs are critical organs. Nitrogen dioxide, carbon, and hydrogen sulfide can form an average inhalation risk in acute exposure [10].

4. Conclusion
In the area where fixed point 6 is located (Kursay district), an extremely high level of inhalation risk (according to the hazard index) for respiratory organs with the total exposure to atmospheric pollutants can form.

An extremely high level of acute non-carcinogenic risk during the inhalation route of entry is formed on the territory of industrial sites.

Based on the generalization of the results of the calculation of inhaled non-carcinogenic acute and chronic health risks, carried out according to the monitoring of Kazhydromet, LHC posts and oil refineries, the results of field studies and materials for calculating the dispersion of pollutants, one can rank the air pollutants in the residential area of Atyrau, highlighting four priority [10]:

I - hydrogen sulfide  
II- suspended solids, fine particles PM 2.5  
III - sulfur dioxide  
IV - nitrogen dioxide

Thus, hydrogen sulfide, a substance with a pronounced unpleasant odor of rotten eggs, is a priority pollutant of atmospheric air in Atyrau. The odor sensitivity threshold is 0.014 mg / m3 (1.75 MPC MR) [10].

The presence of a high risk of air pollutants for human health indicates the need for comprehensive measures to prevent the entry of pollutants into the atmosphere.

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