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ASSESSING THE LEVEL OF ENVIRONMENTAL HEALTH SECURITY AFFECTED BY ATMOSPHERE POLLUTION.

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Abstract

Air pollution poses a significant global threat to the environmental safety. In particular, the air pollution provokes the most comprehensive and negative impact on cities of the Republic of Kazakhstan. This research study focuses on the main atmospheric contaminants and sources of pollution in Almaty city. Moreover, the paper shows a relationship of population diseases with the air pollution of the urban environment. In this regard, the research study proposes a methodology for calculating the index of the environmental safety level for human health under conditions of the air pollution. The probabilistic methods of risk assessment on the basis of analytical method and the method of analogies are applied in this paper in order to calculate the index of the environmental safety for human health. Medical and demographic indicators from the national statistical and demographic yearbooks of the Republic of Kazakhstan were used as the indicators. Calculations on the example of Almaty city confirmed the official data on the critical status of the environmental safety on public health. In this regard, in order to achieve decreasing the level of air pollution in Almaty, the authors proposed recommendations.

Keywords: *Environmental safety, air pollution, emissions, Almaty city.*

1. INTRODUCTION

The environmental security is a component of national security implications for maintaining the balance of the environment in terms of human and technological impacts and their devastating consequences. The concept of the environmental security, on the other hand, has become increasingly divorced from its potentially heterodox and critical roots in human security. The environmental safety being an integral part of the national safety is a major factor for the sustainable development and a basis for conservation of natural systems as well as a maintenance of an appropriate quality of the environment. The Environmental safety includes a safety of the natural and anthropogenic character, which reflects the protection of natural environment and criterion for assessing the security of nature objects and, above all,

the man himself. In addition, environmental security reflects the same objectives with the sustainable development, to ensure the population safety. Environmental security is to be achieved, people must have both healthy natural environmental and some to adapt to change. The relationship between development and human security is a complex. Environmental security is defined as a stable state of protection the socio-techno-natural system against natural and technogenic environmental threats (Ministry of environmental protection of the republic of Kazakhstan, 2004).

Air pollution is one of such global threats to the environmental safety, which poses an extremely harmful threat to human health and life. The major sources of the air pollution are extremely various and are divided into natural and artificial (anthropogenic). The natural sources include: volcanic eruptions, dust storms, forest and steppe fires, fog, particles of sea water, fine sand of deserts and dust from soil erosion, various products of plant, animal, and microbiological origin. Natural sources of pollution have either spread or intermittent spontaneous nature or have a little effect on the overall level of pollution. The anthropogenic sources are the major sources of pollution. In particular, anthropogenic sources include industry, power engineering, construction, and motor transport. Emissions may be solid, liquid or gaseous and have an adverse effect directly on the environment, after chemical transformations into the atmosphere or in combination with other substances. As a result pollutants cause negative changes in a natural composition of the atmosphere, which are accompanied by serious consequences (Ministry for Environmental Protection of the Republic of Kazakhstan, 2011): 1) threats to human and animal health; 2) destruction of the environment or some parts of it (natural regions, regions of living or labor activities), which leads to such impacts on society, which cannot always be calculated in monetary terms, and 3) the deterioration of comfort (eg., odor, deterioration of visibility).

The sudden release of airborne hazardous contaminants in an indoor environment can potentially lead to severe disasters, such as the spread of toxic gasses, fire, and explosion. To prevent and mitigate these disasters it is critical to identify rapidly and accurately the characteristics of the contaminant sources. In addition, remarkable achievements have been made in identifying a single indoor contaminant source in recent years, the issues related to multiple contaminant sources are still challenging (Hao, C., Xianting, L., etc., 2014). The main characteristics of emissions from different sources may be solid, liquid or gaseous, and have a detrimental effect on the environment immediately after chemical reactions in the atmosphere or in combination with other substances.

2. AIR POLLUTION IN KAZAKHSTAN

Air pollution is a contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere. Household combustion devices, motor vehicles, industrial facilities and forest fires are the common sources of the air pollution. The main air pollutants in Kazakhstan are carbon monoxide or carbon monoxide (CO), sulfur oxides, nitrogen dioxide, formaldehyde, phenol, and suspended matters. The main sources of pollution in the industry are the energy, ferrous and nonferrous metallurgy, chemical industry, oil, and gas as well as the construction and motor vehicles.

2.1 The main atmospheric pollutants

The air pollution is actually an impurity of any harmful substances to the atmosphere that causes a detrimental effect on the environment, human health and the quality of life. Air

pollution is a worldwide problem. However, the level of air pollution is mostly high in urban-industrial centers of the developed countries.

Air pollution is a contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere. Household combustion devices, motor vehicles, industrial facilities and forest fires are common sources of the air pollution. Pollutants of the major public health concern include particulate matter, carbon monoxide, ozone, nitrogen dioxide and sulfur dioxide.

According to UNEP, the main air pollutants, which allocate annually to 25 billion tons, include: suspended matters, sulfur oxides (SO2 and SO3), nitrogen oxides (NxOy), carbon oxides (CO and CO2) and formaldehyde (Daniel, A.V., 2007).

Suspended matters. Produced from the burning of fossil and other fuels; the incomplete combustion of fuel in transport, thermal power plants, factories producing construction materials (concrete, wood), while soil erosion, blowing with asphalt cover, etc. causes damage to the respiratory tract malignancies. Affect the respiratory tract and other organs due to toxic effects included in the particle components. Suspended matters cause a disturbance of the respiratory system (bronchi, lungs) and blood circulation.

Sulphur dioxide emitted into the atmosphere during the combustion of fuels containing sulfur (primarily coal and heavy oil). The main source of sulfur dioxide is power plants, boilers, and metallurgical enterprises. Sulphur dioxide has the most negative impact on the upper respiratory tract as well as on membranes of the nose and throat, trachea, and bronchi.

Nitrogen dioxide and nitric oxide are being carried out during combustion of the fuel at very high temperatures and an excess of oxygen. The main sources are: vehicle exhaust gas, emissions of Combined Heat and Power (CHP), solid waste incineration and gas combustion. Oxides of nitrogen are major air pollutants due to their high toxicity. Particularly, oxides of nitrogen can cause changes in the blood by reducing the content of hemoglobin, affects the visual organs, and irritates the lower part of the respiratory system, especially the lung tissue. Moreover, it increases susceptibility to acute respiratory infections, pneumonia.

Carbon monoxide. The main sources are: car exhaust (formed by the incomplete combustion of fossil fuels with an insufficient or poor temperature setting off air supply system for internal combustion engines), CHP emissions, wood burning, fossil fuel, tobacco, and the combustion of solid waste and partial anaerobic decomposition of organic matter. As a result, carbon monoxide reduces the ability of blood to carry oxygen to the tissues, leads to disruption of psychomotor functions, to a violation of cardiac activity and respiration, headache, drowsiness as well as queasiness.

Formaldehyde is emitted into the atmosphere by incomplete combustion of hydrocarbons. The main sources are motor vehicles, power plants, chemical and production of chipboard and fiberboard, plywood, textiles, contained in tobacco smoke. Formaldehyde causes damage to the airways (bronchi, lungs), cancer, mutation, cardiovascular disease, provoking the most negative impact on degenerative changes in the liver, kidney, heart and brain.

On the basis of the above information, it is shown that the main contaminants (pollutants) have physiological effects with the most serious consequences on the human. As a result, pollutants give occasion to lifespan and increasing mortality. According to the World Health Organization (WHO) data on 2012 mortality was 7 million people around the globe, taking into account pollution both in the atmosphere and indoor. Pollution of atmospheric air caused 3, 7 million deaths in urban and rural areas around the globe.

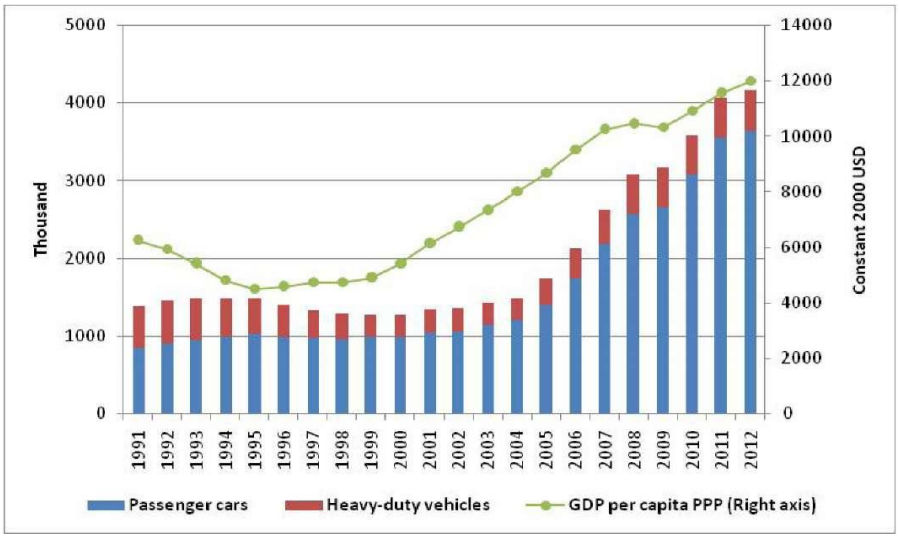
Air pollution is one of the vital issues in Kazakhstan as well. Air pollution is a cause of death of 100 thousand people in Kazakhstan per year and threatens the health of thousands Kazakhstanis, 20% of which are Almaty citizens (Kenessariyev U., Golub, A., and etc., 2013).

The trapped air pollution contains ozone and sulfur dioxide, which cause outstanding issues concerned with health and environment. Exposure to excessive ozone, for example, can cause breathing problems, trigger asthma, reduce lung function and cause lung diseases. Sulfur dioxide causes respiratory and cardiac diseases as well as is the main cause of acid rain. The World Health Organization (WHO) stated that the air pollution is a major environmental risk to health. By reducing air pollution levels, it becomes obvious for countries to reduce the global burden of disease from respiratory infections, heart disease, and lung cancer (WHO, 2014).

The most vital environmental problem in the world's megacities is the growing number of vehicles. In this regard, Kazakhstan is no exception. It is known that the number of vehicles in Kazakhstan has almost tripled over the last decade due to the huge economic growth. As a result, a rapid expansion of the vehicle fleet has resulted in increase emissions of pollutants and greenhouse gasses (Figure 1). Currently, the transport sector is one of the major sources of the air pollution in the country, especially in big cities. By 2012, the car park in Kazakhstan was about 4.1 million units of vehicles, 87% of which are cars. The dynamics of the entire vehicle park from 1990 to 2012 has increased rapidly (Daniel, A.V., 2007).

During the Soviet period of time, the industrial complex of the Republic, especially a manufacturing industry was the source of the annual large amounts of pollutants emissions into the atmosphere. With the getting independence the positive work on the prevention of harmful emissions has begun to carry out. In particular, the legal framework was strengthened, Environmental Code was developed by the country, the concept of ecological security tightened environmental requirements for enterprises with an adopting of the comprehensive program to reduce pollution by period 2009-2018. (Greensalvation, 2009.)

In this regard, the government should introduce strict fuel and emissions standards on cars by meeting the requirements of Euro standards. During machine technical inspection all cars should be checked on the level of produced emissions with an analysis of the air pollution in the big developed cities as well as verifies a good effect on population health (Newsletter of the state of the environment, 2012).

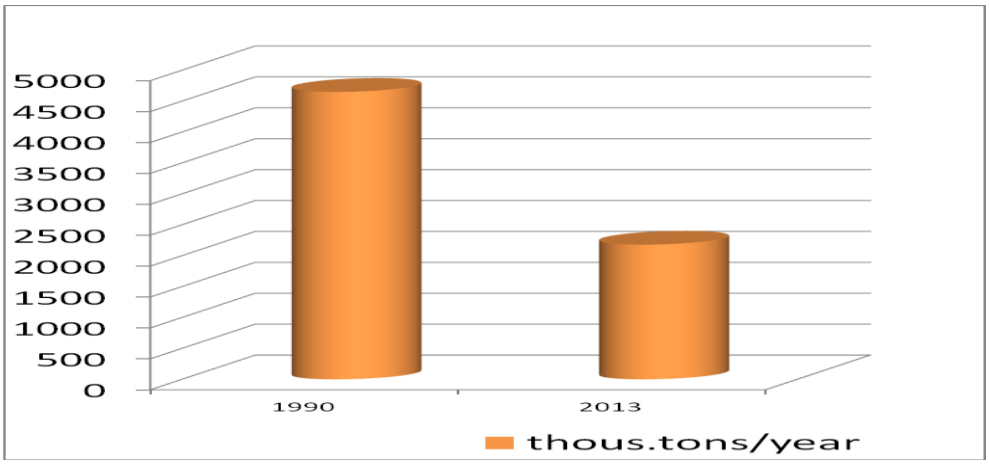


Source: Statistics Agency of the Republic of Kazakhstan, the World Bank

Figure 1. Car park in Kazakhstan

Consequently, the government of the Republic was responsible for taking all the measures to develop the legal background, namely the Environmental Code of the Republic, to adopt the Environmental Safety Concept, to tighten the environmental requirements for enterprises via adopting of the integrated program to reduce pollution by 2009-2018. As a result of these

activities emissions have decreased 2 times in 2013 compared to 1990 and per capita decreased by 67 kg or 33% over the past 10 years (World Bank, 2012).



Source: Statistics Agency of the Republic of Kazakhstan, the World Bank

Figure 2. Air pollution in Kazakhstan

The quality of atmospheric air pollution in Kazakhstan is characterized by the index - API5. It is a comprehensive indicator of the air pollution. For its calculation, 5 indices are selected with the highest numerical value of the maximum permissible concentration (MPC) of contaminants taken separately and summarized.

In our research study, we apply the values of air pollution index for the following impurities: suspended matters; sulfur dioxide, carbon monoxide, nitrogen dioxide, formaldehyde. These data was provided by Kazakhstan Hydrometeorology Service (Kazgidromet) that monitors the environment of the country. According to data analyses of the organization, we have identified seven cities out of 24 cities, which indicators dynamic during the past 5 years show a high degree of contamination from API5 = 7 and above. Among them, the highest rate of the air pollution was in Almaty (Table 1).

Table 1. Atmospheric air pollution

Cities		API_5					Degree of pollution
		2010	2011	2012	2013	2014	
1.	**Shymkent**	11,4	13,3	10,0	8,6	10,7	High (7-14)
2.	**Temirtau**	9,3	10,2	9,3	6,9	8,1	
3.	**Almaty**	11,7	9,1	10,5	11,5	10,0	
4.	**Ust-Kamenogorsk**	7,2	8,4	7,9	7,6	10,4	
5.	**Karaganda**	7,2	7,8	6,4	7,0	7,7	
6.	**Taraz**	7,6	7,6	7,7	7,4	6,9	
7.	**Zhezkazgan**	7,0	7,1	7,5	6,5	7,3	

Source: The annual information bulletin of Kazgidromet

2.2 Analysis of the air pollution dynamics in Almaty city

Almaty is the biggest city in Kazakhstan, with a population about 1,6 million people and a total area - 324.8 km2. Almaty is a financial, economic, trade, cultural and scientific center of

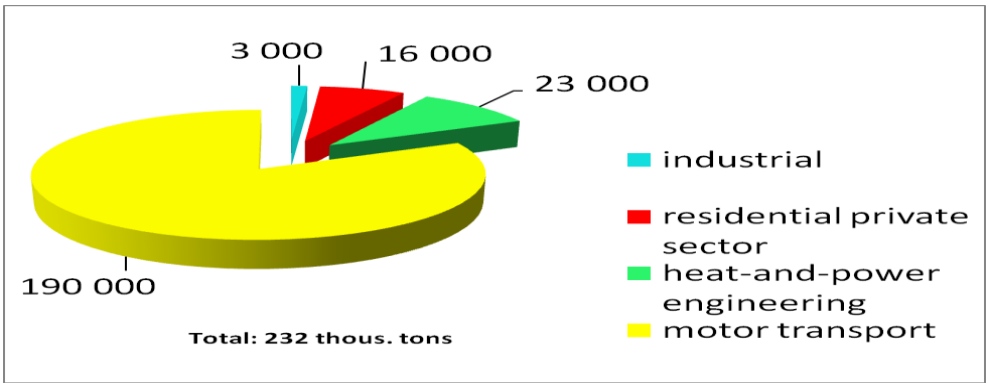
the republic. The air pollution in Almaty is triggered first of all due to the climatic features. A significant indicator of improving the quality of life is a geographical aspect, particularly, the location of the city (Di Felice, P., 2015). The city is located in a submontane depression, so is characterized by the absence of the wind, fogs, and ground inversions, which impede dispersion of contaminants in the space. During the cold season, temperature inversions lead to continuous accumulation of pollution products in the form of smog in the surface layer.

The air pollution in Almaty is caused by several reasons. Firstly, incinerators and waste disposals, forest, and agricultural fires serve as natural sources of the air pollution. Secondly, transport emissions cause the air pollution in the city. According to the traffic statistics of the Almaty, the number of cars reached 500,000 by the end of 2012 and continues to increase yearly (Oxikbayev, K., 2014).

According to the NYC Partnership Consulting in January 2010, Almaty took 25th place in the list of most polluted cities around the globe. However, it should be noted that Almaty is a very beautiful, green city. Almaty is located at the foot of the northern slope of the Ili Alatau at an altitude of 600 m to 900 m.

The population of Almaty, mostly those, who live in the lower part of the city, suffer heavily from air pollution. Increasing the level of smog and density of airborne in Almaty has a negative effect on the environment and health of citizens. Their reasons of the air pollution vary on its nature. As Almaty is not an industrial city, over 85 percent of pollution is the result of transport-related exhausts. The total amount of emissions in 2012 was about 232 thousand tons with a significant proportion of vehicles 190 thousand or more than 82% (Figure 3).

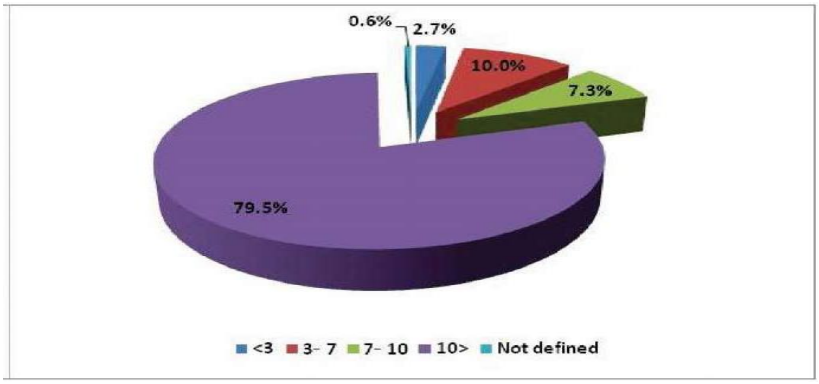
The level of polluted air in Almaty reached a very high level, leading to the damage of people's health. Population health depends on many complex interactions. In particular, among them is a state of the Physical environment (Santana P. et al., 2015).



Source: Comprehensive Program to reduce the environmental pollution of Almaty city for 2009—2018.

Figure 3. The volume of pollutants emissions into the atmosphere of Almaty in 2012

The rapid economic growth coupled with an increasing prosperity of the population has led to a tripling of vehicles density since 2003 and amounted to 21.3 units per 100 people in 2012 year. According to the report, Almaty and Astana are cities with the highest density of vehicles in the country. However, increasing the number of vehicles was largely due to the import of old cars. Thus, at present, nearly 80% of the vehicles in the country are aged over 10 years, 90% of which about are in Almaty (Figure 4).



Source: http://mvd.gov.kz/portal

Figure 4. Age distribution of passenger cars

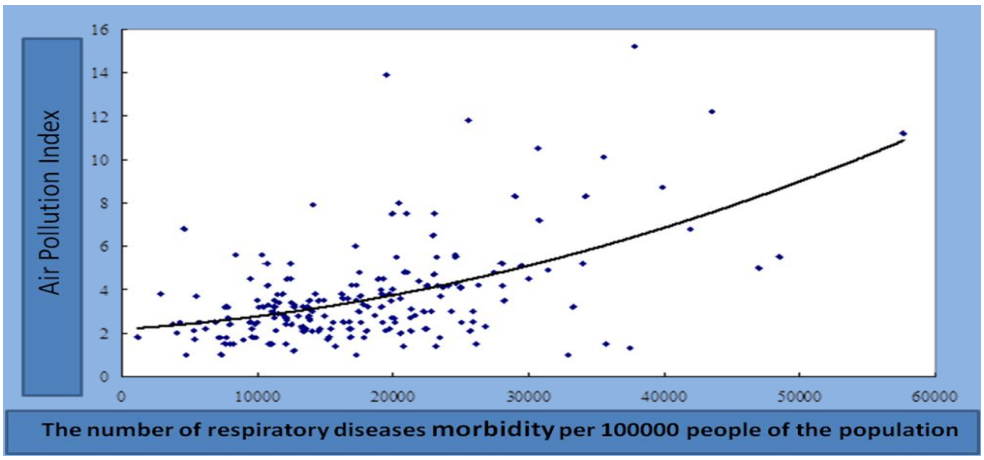
Therefore, the presented analysis on the air pollution dynamics in Almaty, by the multiplicity of the excess of maximum permissible concentration in the last 5 years shows the over limits of nitrogen dioxide. The greatest contribution to the air pollution made the formaldehyde, cars, power plants, and emissions of solid waste incineration (Table 2).

Table 2. The dynamics of air pollution in Almaty (by the multiplicity of excess of the MPC)

Contaminants	2010	2011	2012	2013	2014
Suspended matters	1,3	n	1.1	n	0,9
Nitrogen dioxide (NO_2)	2,8	2,1	2,5	3,4	1,9
Carbon oxide(CO)	n	n	n	n	0,5
Sulfur dioxide (SO_2)	n	n	n	n	0,7
Nitrogen oxide (NO)	n	n	n	n	0,2
Formaldehyde	4,7	3,2	3,4	3,2	3,7
Phenol	n	n	n	n	0,4
		n – normal			

Source: The annual information bulletin of Kazgidromet

However, the major sources of the air pollution in Almaty are the exhaust gasses of vehicles, emissions of heat electro power stations and combustion of solid waste. It becomes evident that the air pollution has a serious impact on public health and safety. Poor air quality causes cardiovascular and respiratory diseases such as asthma and bronchitis. In addition, the air pollution increases the risk of lung cancer.



Source: Almaty, 2010.

Figure 5. The correlation between air quality and respiratory diseases morbidity of population in Kazakhstan

Cardiovascular diseases are the leading cause of death in Kazakhstan. On the other hand, according to national statistics, respiratory diseases such as asthma and other chronic lung diseases, affect over 50,000 people annually.

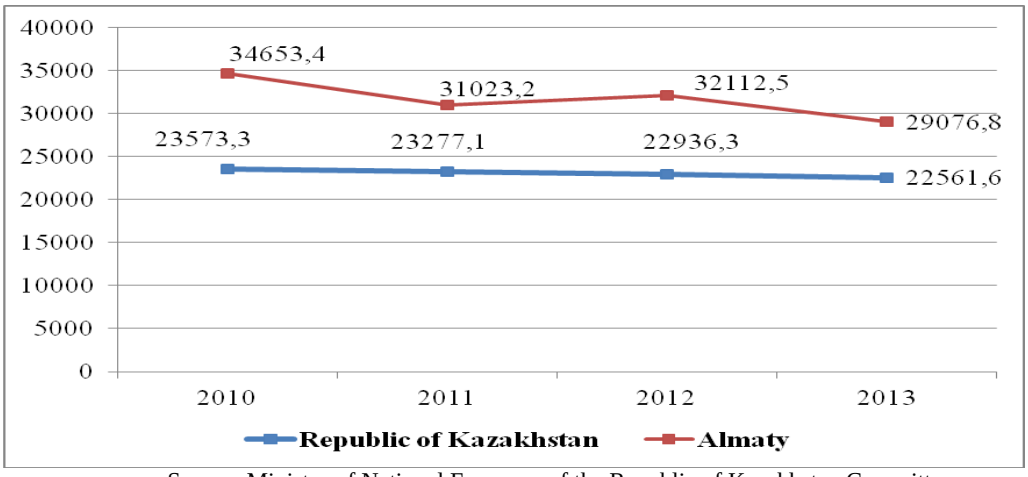
From Figure 5 we can see the close correlation between air quality and respiratory diseases in the population of Kazakhstan.

Almaty oblast and Almaty city with a concentration of more than 25.6% of the total car park have a significantly higher incidence of respiratory diseases. In 2012, the highest number of respiratory diseases reported in Almaty 1.5 times higher than the average in the entire country (Table 3).

Table 3. Security levels for public health

Index	Levels of safety	
I	more than 0,9	High
II	0,9 – 0,8	Acceptable
III	0,8 – 0,7	Average
IV	0,7 – 0,6	Critical
V	less than 0,6	Catastrophic

Thus, the air pollution has a direct negative impact on public health and is the most pressing environmental issue requiring urgent solutions. In our research, we have attempted to show the impact of environmental pollution risk by calculating the level of the environmental safety for population health in Kazakhstan.



Source: Ministry of National Economy of the Republic of Kazakhstan Committee on Statistics Statistical Yearbook. Astana, 2013.

Figure 6. Indicators of respiratory diseases from 2010 to 2013, per 100 thous. of people

3. THE CASE STUDY

3.1 Research Methodology.

The formula for calculating the environmental health security index was obtained by using probabilistic risk assessment methods based on analytical method and method of analogies. The most generalized and meaningful indicators of the population health are the incidence index and the average life expectancy.

From these data, we can calculate the safety performance of Public Health (KSPH) according to the following formula:

$$K_{SPH} = \sum_{i}^{n} \frac{I_{MRY\,i}}{I_{MPY\,i}} \left(1 - \frac{L_{max} - L_i}{L_{max}}\right) \frac{H_i}{H}$$

where n – number of districts;

$I_{MRY\,i}$ – morbidity index of the reporting year of the i-th district;

$I_{MPY\,i}$ – morbidity index of the year previous to the reporting year;

L_i – the average life expectancy in the i-th district;

L_{max} – the maximum recorded average life expectancy (in Japan);

Hi, H – the population size of the i-th district and the total population size.

The indicator of the ecological safety is calculated by regions, taking into account regional specificities and drawing parallels with the assessment of the environment in the context of the administrative-territorial units. In accordance with the five-point scale, we define security levels for the human health (Table 3).

As an example, we can calculate the rate of health security in Almaty as the most polluted city in terms API5. Consequently, both with relying on the above formula and according to the statistics of Almaty, we retrieve the quantitative data on the index of public health safety in Almaty for 2011-2012:

IMRYi– morbidity index of the reporting year - 32 112, 5/100 000 (for 2012);

IMPYi – morbidity index of the year previous to the reporting year -31 023,2/100 000 (for 2011);

Li – the average life expectancy in Almaty – 71,61;

Lmax – the maximum recorded average life expectancy (in Japan) – 82,6;

H –population size in Almaty – 1 414 000;
Hi – total population size in Almaty region -1 909 362.
Calculation of the index on public health safety in Almaty:

$$K_{SPH} = \frac{0{,}32112}{0{,}31023} \times \left(1 - \frac{82{,}6 - 71{,}61}{82{,}6}\right) \times \frac{1414000}{1909362}$$

$$K_{SPH} = 0{,}66$$

In Table 3 the five indices are shown with appropriate levels of security to public health, which is presented as high, acceptable, medium, critical and catastrophic. According to Table 4, the level of public health safety in Almaty is critical. Therefore, we consider that it is necessary that the government takes measures to improve air quality in the city and develops programs to reduce environmental risks.

3.2 Discussion of results and recommendations to the environmental health security

As mentioned previously, the environmental pollution can cause a number of environmentally-related diseases and, in general, leads to a reduction in average life expectancy of people. Therefore, the average life expectancy of people is the main criterion of the environmental safety. An environmental hazard is a threat of a negative effect on the composition or character of the environment caused by anthropogenic impact. With respect to human, the environmental hazard is a threat to health and even human life. Furthermore, the environmental safety is reciprocal to the environmental hazard. It means that the greater is the hazard, the lower is the safety, and vice versa. In our research study, the level of the environmental safety meets the level of admissible risk as equal to 0, 8-0, 9.

Quantitative evaluation of the environment quality or its separate main component can be made: 1) by means of indicators, 2) with the use of quality indices or 3) bringing the concept of environmental risk. In order to find out a practical application on the system of criteria, it must be based on the existing normative legal and information base. Otherwise, due to lack, or absence or unrepresentativeness of the original information, practical calculations of necessary indicators will be extremely difficult or impossible.

Informational and methodological basis for obtaining the environmental indicators in the countries of EECCA provide (Eastern Europe, Caucasus, Central Asia) are: (Heil M., Pargal S. 1998)

- the state statistical information
- agency-level information
- methodological development for the recording of environmental parameters in the documents defining the strategy of development of economy sectors
- Scientific publications and development.

According to the national monitoring system, for domestic enterprises with the first category of hazard, the major evaluation indicators of the impact on the environment are emissions, discharges and production waste. But not at any factor can be considered as an indicator. A particular indicator must meet certain requirements: be scientifically substantiated; sensitive; have a simple interpretation; be capable of aggregation; be original element of information on the basis of which quantitative assessments can be carried out; have a representativeness and be constructive; have a high information capacity and carry out

a new valuable information for decision-making systems (Environmental Monitoring…, Geneva, 2007).

Successfully found environmental indicators and quality indices allow to the development of system models in order to create a unified methodology, enabling to mathematically process and obtain compact information about the quality of the environment in numerical values and convenient for graphic and cartographic visualization. The indicators are divided into different levels: global, regional, national and local. Currently, the world practice establishes that it is reasonable to rank the system of indicators by levels of priority (Sherbinin, A., Reuben, A., etc., 2013). UNDP project for the Central Asian countries proposes five key indicators for the CIS countries. The indicators are constructed in such a way as to provide a quantitative characteristic of the selected problems, relying on the database of the national statistics (Ministry for Environmental Protection of the Republic of Kazakhstan, 2012).

We conditionally divided the environmental safety in the region into two internal units: anthropogenic impact on the environment and medical and demographic characteristics of the region. The anthropogenic impact of vehicles on the environment with the most detrimental effect on the environment have been described above. Medical and demographic characteristics of the region were used as indicators for quantitative calculations. As a result, the morbidity index of the accounting year in Almaty for 2012, the morbidity index for 2011, the average life expectancy in Almaty and the maximum registered average life expectancy (in Japan), as well as the population size in Almaty and the total population size of the region were calculated. Thus, this system of indicators in the proposed method allows getting an idea of the environmental safety of human health in the region in the form of quantitative data, along with traditional one.

3.3 Recommendations.

We offer the following recommendations to reduce the impact of the air pollution on population health and increasing the level of the environmental safety:

- normative and legal regulation;
- priority development of public transport
- the restriction of private vehicles;
- transition to the alternative kinds of fuel: gas, electricity, bio-fuel.

4. CONCLUSIONS

Thus, an important element of ensuring the environmental safety is the health of the population. Human health and life expectancy depend on many factors, particularly on clean environment and enabling high-quality food, quality health care, and other factors such as genetic predisposition, lifestyle, and physical education should be guaranteed by the state. Accordingly, the preservation and enhancement of public health in this context is an essential element of the environmental safety, as the population of the republic is not only an economic resource of the state but also represents its potential socio-economic development.

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