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Medical aspects of atmosphere pollution in Tbilisi, Georgia

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Abstract

Climate change and its impact on ecosystems is one of the main problem of 21st century. Increase in green house gas in the atmosphere was regarded as an important cause. Atmospheric composition had significantly changed due to intensive technogenic pollution. Increase in aerosol (solid, liquid and gas) concentration had serious impact on human health and raised the level of risk factors for longevity of life. Despite, global character of climatic change and its intensity in numerous ways was influenced by local specificity of regions, their geographical location and meteorological factors. A study on the atmospheric quality (quantitative and percentage estimation of aerosols) of Georgia was carried out. Also the assessment of impact of meteorological and ecological conditions on human health was made for Tbilisi city. A relation between contaminants and meteorological factors was evaluated, particularly gas pollutants were strongly correlated with each other due to their photochemical activity; positive correlation (0.65; 0.69) between air temperature and pollutants. All the contaminants showed negative correlation with relative humidity, due to hydrolyzing ability. On the basis of multi-factorial statistical analysis, correlation between ambulance call, weather type, atmosphere pollution index, change in ground ozone quantity and earth magnetic field were determined. Atmospheric pollution due to dust, carbon, sulfur and nitrogen oxides, ground ozone quantity in Tbilisi significantly exceeded maximum permissible level, that effected human health.

Key words

Climate change, Green-house gases, Human health, Meteorological factors, Tbilisi

Introduction

The issues of climatic change and techno genic load of the environment are not only scientific, but also economic and political problems of the modern world. The mistakes made in the dynamics of these phenomena have lead to economic disasters and have become an issue for the survival mankind (Dogan and Ozturk, 1991; 1994 a,b). General issues of atmospheric pollution of the world have been described in detail in the Atlas of Atmospheric Pollution of the World (World Atlas of Atmospheric Pollution, 2011).

At present, one of the most serious problems of the world is global environmental pollution caused due to climatic change. Following the development of civilization, man has altered the environment and whole ecosystem leading to the deterioration of social environment and state of health, globally (Jacobson, 2002).

It is now a known fact that the industrial emission is doubling world wide in every 8-10 years, while vehicle pollution reaches 80%, CO concentration exceeds almost 10 times the MCL and the level of nitrogen and sulfur compounds, benz (a) pyrene, aldehydes and other contaminants in the atmosphere keeps on increasing. The maximum permissible limit is fixed for more than 200 different admixtures, but as they are present in the atmosphere at the same time, their cumulative impact is much stronger than their individual effect (Kharchilava *et al.,* 1998).

In Georgia, The main pollutants are dust, carbon, nitrogen and sulfuric compounds, soot, cement etc. The maximum concentration in different cities of Georgia, such as Tbilisi, Rustavi, Kutaisi, Zestaphoni, Kaspi and others, exceed the maximum permissible level and result from the above-listed factors and meteorological processes, climatic and geographical conditions typical to Georgia, vary in different years and seasons as well as according to the territorial propagation (Lagidze *et al.,* 1997).

Different admixtures cause or spread different diseases, such as: cardiovascular disorders, respiratory tract problems, nervous system disturbances, allergies, blood diseases, decrease in immune-biological reactivity, certain types of cancers and many more (Bhola *et al.,* 2010).

The problem of climate change is associated with the processes taking place in nature and anthropogenic factors. The anthropogenic factors, as background of the impact of global and regional climatic factors in different regions of Georgia, may lead to microclimatic changes (Main, 1981; Gunia, 2005).

Under the influence of natural processes and anthropogenic factors, the admixtures of different pollutants of different origin and different density get into the atmosphere and hydrosphere almost continuously. The duration of their life and diffusion mostly depends on the vertical distribution of the density of admixtures, which is particularly important due to the complex physico-geographical and climatic conditions of Georgia. The impact of climate change regarding Georgia's vulnerable regions have been discussed at length by Matchavariani and Lagidze (2012).

The process of modern climatic changes occurs with minor growth of the state of energy, but for a long time (over a century). This process of tendentious growth is characterized by variations of different intensities. Intense variations lead to atmospheric phenomena with undesirable and often catastrophic outcomes. One of the major measures to mitigate the climatic changes is reduction of “greenhouse gases” from anthropogenic emissions. Vehicles are the principle source of anthropogenic emission of greenhouse gases. This is particularly obvious on the background of less developed industrial branches in Georgia. Considering the complex relief of the country, building shorter sections of tunnels and roads have a great potential to reduce the emission of “greenhouse gases” from vehicles associated with significant environmental efficiency. The share of greenhouse gases in the aggregate CO_2 emission in Georgia during past few year have been 30-35% (Gunia and Saralidze, 2009). The present study aims to present the qualitative state of air (quantitative and percentage assessment of aerosols) in Georgia and an assessment of the impact of meteorological-climate and environmental conditions on human health in Tbilisi, capital of Georgia. Tbilisi is located 400-500 m above sea level, in the gorge of Mtkvari river and is characterized by heavy atmospheric pollution.

Materials and Methods

The data obtained from the Ministry of Environmental Protection and Natural Resources of Georgia and Department of Statistics of Georgia were subjected to multi factorial statistical analysis (Kobisheva, Narovilianski, 1978), and weather medical assessment index was introduced to assess environmental and meteorological impacts on human health (Lagidze *et al.,* 2005):

$$i = i_{clim.} + i_{poll.} + i_{oz.} \qquad (1)$$

where $i_{poll.} = \sum (q_{av.})\, Ci$; $q_{av.}$ = average admixture concentration; Ci – is the biological activity class of admixture.

Lesser the class value, more harmful is the substance. This value changes from 1 to 4. Lead belongs to class I of biological activity, NO belongs to class II, dust to class III and CO to class IV, respectively.

Pollution index i_{poll} means atmospheric pollution with dust, CO, SO_2 and NO_2, as well as magnetic storms (a significant increase in the horizontal component of the earth magnetic field); $i_{oz.}$ shows ozone content in the ground air layer, and $i_{clim.}$ is the impact of climatic factor. To consider the ozone factor, its impact on the weather indicator during different degrees of the atmospheric pollution was studied.

Results and Discussion

The data obtained from the Department of Statistics related to the substances emitted in the atmosphere from permanent sources on the basis of percentage value was found in the following order: hydrocarbons followed by carbon monoxide, oxides, sulfuric anhydride and so on (McMichael, 2002; McMichael *et al*., 2003). The dynamics of atmospheric pollution since 1990s has been found to be non-stable. Following the economic state of Georgia in 1990-1992; in terms of stagnant industrial sector and lack of fuel; the quality of atmospheric air improved temporarily. Transport has been the major source of air pollution in Georgia, which started revitalization from 1995, with its share in air pollution reaching 80-85%. Since 2001, the emissions in the atmosphere from the vehicles have been added gradually than the emissions from the industrial sector (Lagidze, *et al*., 2013). Due to partial revitalization of the latter, one must admit that the industrial sector would reach gigantic scales of development step by step (Fig. 1).

The dynamics of the substance emissions in the atmosphere in different cities and for different enterprises in 2005-2010 is given in Fig. 2.

The leading role of transport sector in atmospheric air pollution is evidenced by results of the comparative analysis of the amount of substances harmful to human health, emitted in the atmosphere from some enterprises of certain branches, suggesting vehicles (44.44%), agriculture (27.43%), power engineering (24.28%) and industry (3.86%) to be the major sources of atmospheric pollution (Table 1). The dynamics of the amount of emission in country from vehicles for last 5 years showed increase in aerosols (Fig. 3).

The analysis of dynamics of quantitative variation of the emission in the atmosphere from vehicles showed that since 2005, the amount of individual pollutants, like sulfuric anhydride, nitrogen oxides, hydrocarbons and other substances in the total amount of aerosols increased.

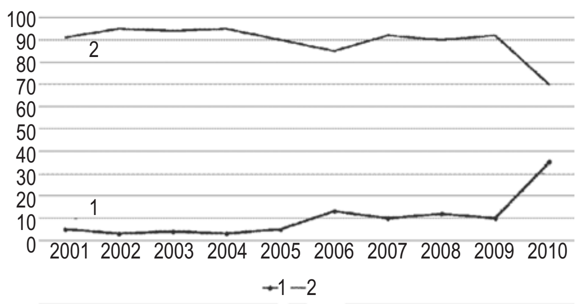

Fig. 1 : Share of industry (1) and vehicles (2) in the total atmospheric air pollution, % (2006-2010)

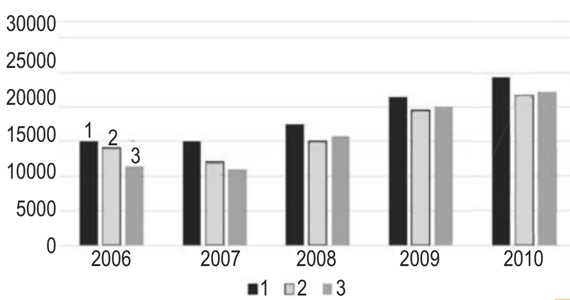

Fig. 2 : Dynamics of changes of the quantitative emissions of harmful substances in the atmospheric air, t (2006-2010)

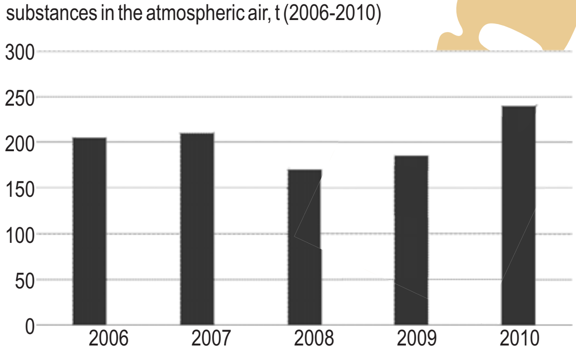

Fig. 3 : Dynamics of variation of the quantities of the emissions from the vehicles in 2006-2010 (thousand tons)

The power engineering sector plays an important role in atmospheric pollution, by emitting major proportion of atmospheric emissions (without considering carbonic acid as a non-harmful substance), constituting of hydrocarbons, volatile organic substances, carbonic acid and solid particles (dust). In 2010, 134305 tons of harmful substances without carbonic acid were emitted in the atmosphere from the power engineering sector (Table 2).

Out of the harmful substances emitted in the atmospheric air from different sectors of economy, carbon monoxide ranked first (CO – 39%), followed by methane (21.6%), hydrocarbons (20.5%), solid particles, inorganic dust (6.3%) and almost the same proportion of ammonia and nitrogen oxides (5%) (Table 3), respectively.

The meteorological processes have a significant impact on the spatial-time distribution of aerosols in the atmosphere. The impact of meteorological elements on the atmospheric pollution was studied firstly by identifying the periods of severe pollution of the atmosphere, followed by correlation between degree of air pollution and meteorological parameters (Matchavariani and Lagidze, 2012). The predictors of correlations were taken as the change of wind direction and velocity, air temperature, state of atmosphere, precipitations, humidity, water vapor elasticity and minor cloudiness. The analysis of correlation between atmosphere polluting ingredients and meteorological elements evidenced that the gaseous pollutants were strongly correlated with each another. As a result of photochemical activity of these ingredients, their interaction during warm period was stronger than cold period. Dust was not in correlated with SO_2, CO and NO_2, as the sources of these gases were different. Dust and SO_2 were washed down by the precipitation, which is typical to any season. Snow cleared the atmosphere off the harmful admixtures better than rain did. CO and NO_2 were not washed down by precipitation due to their physico-chemical properties. SO_2 and NO_2 were correlated with temperature. A positive correlation of these elements with temperature was identified (0.65; 0.67) as Greenhouse Effect. During cold period, CO showed negative correlation with temperature as a result of increased intensity of

Table 1 : Quantitative indicators of the harmful substances emitted in the atmosphere from different sectors of economy (2010)

Emissions of harmful substances from the sector of economy	Indicator of the annual atmospheric air emissions (with t / year in numerator and % in denominator)	
	without carbonic acid	with carbonic acid
Vehicles	245858/44.44	2124463/16.00
Power engineering	134305/24.28	10494644/79.03
Industry	21335/3.86	508570/3.83
Agriculture	151738/27.43	151738/1.14
Total	553236/100	13279415/100

Table 2 : Emission of polluting substances (t yr^{-1}) in the atmosphere from power engineering sector in 2010

Substance emitted in the atmospheric air	Coal	Liquid air	Oil	Fuel oil	Natural gas	Timber	Total
Solid particles	6984,1	–	77,3	13,4	–	98,04	16879,8
Carbon monoxide	5285,1	7788,0	1900,9	167,7	10596,9	13920,6	39659,2
Sulfur dioxide	3141,8	–	–	479,9	–	–	3621,7
Nitrogen oxides	115,0	443,0	104,6	51,5	6906,5	360,7	7981,3
Hydrocarbons	–	1415,9	3643,4	-	6103,7	–	66163,0
Benz(a)pyrene	0,000152	–	–	0,000047	0,1105724	–	0,110771
Carbonic acid	133460,3	34834,1	125013,9	41512,4	2735100,9	7290419,1	10360339,0

Table 3 : Quantitative and percentage ratios of different harmful substances emitted in the atmosphere from different sectors of economy in 2010

Substance emitted in the atmospheric air	Quantitative specifications of emission	
	t yr^{-1}	%
Solid particles (inorganic dust)	34825.9	6.30
Soot	3972.0	0.72
Carbon monoxide	218161.4	39.43
Sulfur dioxide	9326.1	1.69
Nitrogen oxides	25862.5	4.67
Hydrocarbons	113408.2	20.5
Ammonia	27259.1	4.93
Hydrogen sulfide	731.9	0.13
Methane	119688.1	21.63

Table 4 : Dynamics of mortality caused by cardiovascular pathologies in different seasons

Cases of mortality	Season			
	Winter	Spring	Summer	Autumn
General	1778	1663	1343	1408
Due to cardiovascular pathologies	964	863	677	713

ground inversion due to temperature fall at the ground surface. CO concentration was closely linked to the ground inversion (correlation coefficient is 0.69). A positive correlation between CO and temperature was detected during cold period of the year, a result of greenhouse effect. All polluting ingredients were negatively correlated with relative humidity which could be explained by the hydrolysing ability of these ingredients. The concentration of ground ozone was negatively correlated with dust concentration (0.39±0.02), as town dusting reduced UV radiation and hampered the photochemical formation of ozone. During cold period of the year, ozone was negatively correlated with NO_2 (0.4±0.02), which could be explained by ozone destruction due to strong pollution, little duration of sunshine and low temperature. During warm period of the year, ozone showed positive correlation with NO_2, as photochemical pollution depends on the solar radiation and temperature.

The amount of different aerosols in the atmosphere (industrial dust, nitrogen and sulfuric compounds, soot, cement, etc.) exceeding maximum permissible level were found in industrial cities as a result of local sources as well as diversified meteorological and complex physical-geographical and climatic conditions of Georgia. The different regions of Tbilisi, with their individual micro-climatic peculiarities, helped in accumulation of aerosols in the city center.

The said admixtures caused different diseases and medical complications, which were also promoted by relief and climatic conditions. Climatic-environmental factors like air temperature, humidity, atmospheric pressure, inversion, isothermy, synoptic processes, etc. played an important role in provoking different diseases.

The work followed the statistics applied to the emergency medical service by the patients with cardiovascular pathologies during different seasons. The data showed that emergency was most frequently called in winter, mostly at 6 pm during the day. In both cases, the atmospheric pollution in Tbilisi was maximum. Table 4 shows the statistics of mortality caused by cardiovascular pathologies, according to which, mortality reached its peak during winter, mostly due to pollution.

A conclusion can be made while considering the strong atmospheric pollution in Tbilisi promoted by the geography and meteorological conditions of the capital (Amiranashvili *et al.*, 2012). Tbilisi is located in the basin and characterized by stills, inversions, and isothermy processes. Besides, the city has been wrongly planned. It has narrow streets and high buildings hamper ventilation; the traffic is overloaded and only the streets and buildings in the city center are subject to wet treatment.

As a result, CO and dust content in the atmosphere was very high, with their average monthly values exceeding the maximum permissible concentration by 4 or 5 times, and their single concentration exceeded the standard by 20 to 30 times. It should also be noted that dust in Tbilisi contained toxic substances like lead, titanium, copper, manganese, etc.

In order to study the atmospheric pollution problem, weather medical assessment index (formula 1) was calculated.

Table 5 : Dependence of number of calling the emergency medical service due to cardiovascular pathologies on weather and helio-physical indices (for different degrees of atmospheric pollution)

#	Degree of atmospheric pollution	Comforting index of the ground ozone content	Value of the horizontal component of the earth's magnetic field	Type of weather	Number of calling the emergency medical service due to cardiovascular pathologies
1	4.3±0.10	2.8±2.32	48±5.3	Annoying	11151±31.0
2	3.4±0.19	8.7±1.19	151±29,0	Annoying	1085±15.0
3	3.4±0.06	8.0.±0.90	46±3.5	Annoying	1087±23.0
4	3.3±0.04	4.30±2.75	42±2.2	Annoying	977±17.0
5	2.3±0.14	46.0±4.54	111±7.0	Optimal	8987±24.0
6	2.4±0.03	5.4±1.70	45±1.0	Optimal	910±8.0
7	1.8±0.03	48.0±4.07	44±2.8	Optimal	840±14.0

Table 6 : Seasonal dynamics of weather types

Seasons	Types of weather		
	Comforting	**Annoying**	**Severe**
Winter	3%	10%	87%
Spring	11%	31%	58%
Summer	43%	38%	19%
Autumn	35%	26%	39%

The ozone factor was considered by studying its impact on the type of weather for different degrees of atmospheric pollution with the following conclusion: During cold period of the year, during temperature inversion and cloudy weather, when atmospheric pollution is strong, then the ozone content is less than its optimal value. In such case, the disinfecting ability of the atmosphere is reduced and general as well as cardiovascular diseases exacerbate. During warm period of the year, with minor atmospheric pollution and ozone concentration was within the limit of 40 mg m^{-3}, the number of cases of calling the emergency medical service was minimum. Table 5 shows the dependence of number of calling the emergency medical service due to cardiovascular pathologies related to atmospheric pollution, ozone content, index of magnetic storms and type of weather.

Table 5 shows severe exacerbations of cardiovascular diseases that had occurred during strong atmospheric pollution (API – 3; 4), low ozone concentration and annoying weather conditions. A combined impact of these three factors on the occurrence of diseases was so strong that the role of magnetic storms was considered insignificant. In terms of average atmospheric pollution and optimal weather, the impact of ozone content and magnetic storms on cardiovascular diseases was well seen. Thus, these two factors, as well as atmospheric pollution and meteorological factors lead to the exacerbations of cardiovascular pathologies and should be considered during medical examinations.

In order to evaluate the reliability of formula, different cases of weather conditions were modeled by considering different degrees of atmospheric pollution and content of ground ozone. The results evidenced that ranging variation of weather medical assessment index from 0 to 49 was considered comforting, 50 to 80 was considered annoying and above 80 was severe.

Indexes calculated for one day in July, as an example, according to formula (1), revealed weather pathogenic index $i_{clim.=}$24, atmospheric pollution index $i_{oz.}$=25, ozone content comforting index $i_{poll.=}$20. Thereafter, the weather medical assessment index i, as their sum, was equal to i= 69, *i.e.* the weather was annoying. The results of the weather medical assessment index calculations are given in Table 6. Analysis of this table, winter revealed was that discomforting in Tbilisi (with 87% of disease exacerbation), summer was comforting (with 19% of disease exacerbation), and exacerbation was more frequent during spring than in autumn.

Suchwise, the impact of meteorological conditions on the atmospheric pollution is identified. A multi factorial statistical analysis was used to identify correlation between the intensity of calling medical emergency service, types of weather (in a medical respect), index of atmospheric pollution, content of ground ozone and earth's magnetic field variations.The statistics of mortality due to different diseases in different seasons are fixed, in particular, the mortality caused by general as well as cardiovascular diseases is highest in winter, explained by the correlation between the atmospheric pollution and meteorological processes (inversion, isothermy, shtill). The variation of the weather medical assessment index from 0 to 49 is considered comforting, index from 50 to 80 was considered annoying and it was severe over 80.

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