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Physical Geography

Marine Influence on the Atmospheric Pollution in the Ajara Coastal Zone

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ABSTRACT. The influence of aerosols of marine and continental origin on the level of atmospheric pollution is studied for the coastal zone (Ajara as an example). The influence of variations of the level of atmospheric pollution on the number of parameters forming the climate – temperature, water vapor resilience, relative humidity and wind speed has been considered. *© 2010 Bull. Georg. Natl. Acad. Sci.*

Key words**:** *Ajara coastal zone, global warming, aerosol, dust particles, atmospheric pollution.*

Current global warming process is caused by destruction of sustainable balance of the energetic level of the sun-atmosphere and the earth surface. One of the important factors of destruction of conditions of balance of the energetic level is the trend of increasing atmospheric pollution. Due to the above-mentioned, atmospheric pollution has become one of the main problems.

As is generally known, numerous factors are involved in climate forming, among them it is important to know what impact has the sea on atmospheric pollution and what is the importance of marine aerosol particles that are in the atmosphere in the process of climate forming.

It has been known that dust particles (atmospheric aerosols) are permanently present in the atmosphere, but they were not considered to have any impact on the atmospheric processes and serious attention was not paid to them. Today the atmospheric aerosols or atmospheric pollution is one of the most important problems of mankind. In the references one comes acros quite different definitions of atmospheric pollution. The case is that each of them agrees with the specificity of the task and such approach is often reasonable.

As our task belongs to the sphere of studying the impact on the energetics of the atmospheric processes, the following definition of atmospheric pollution is acceptable (it was formed in the middle of the 20th century): we can name part of the composition of the atmosphere "atmospheric pollution", excluding from it nitrogen, oxygen, ozone, carbon dioxide and water vapor.

As far as we know, the first, more or less argumentative statement was made by the German scientist L. Rassow [1]. From 1936, for 20 years he had measured permanently the amount of deposited dust in one of the industrial regions of Germany and came to the conclusion that during this period atmospheric air pollution had increased three and more times. Howerever, a scientifically proven idea about the tendency to variability of atmospheric dust and its anticipated results was stated later. Its author was Academician Th. Davitaia.

According to Davitaia's hypothesis, increase of anthropogenic pollution of the atmosphere has an important impact on the process of global climate change [2]. Besides, increase of atmospheric pollution can cause both warming and falling of temperature. Namely, if concentration of aerosols in the atmosphere is below a certain critical level, it can cause warming, but when the

concentration of aerosols in the atmosphere exceeds the critical level, then a cold snap can occur.

Thus, the atmospheric aerosols are able both to increase the energetic level of the earth and its reduction. The process of increase is due to the circumstances that, firstly, the aerosols change the albedo owing to their deposition on the underlying surface [2], and secondly - owing to absorption in the atmosphere they can act as greenhouse gases [3]. As for decreasing, it is due to the influence of atmospheric aerosols on the process of dispersion of radial energy.

Atmospheric aerosols are generated mainly by the cosmos and the earth itself. Cosmic aerosols are generated due to burning of cosmic bodies, intruding in the atmosphere incidentally. As for the earth aerosols, four main sources of their generation are distinguished [4]:

- ocean and marine surfaces, where 10^{18}-10^{20} air balloons explode per second, due to which numerous small particles (salts) get to the atmosphere;

- mineral aerosols, which occur from the surface of the soil devoid of green cover;

- vegetation dust and spores, created by the green vegetation cover; and

- aerosols of organic origin. They occur in the process of decomposition, thus causing the creation of different microorganisms and numerous viruses.

Aerosols, entering the atmosphere from different sources, overstay there for different periods depending on their resilience and sizes. Relatively large particles are sedimented rapidly. As for small particles carried off by circular processes, they can remain in the atmosphere for a long time. In this regard, a very interesting and original theory as a kinetic model of atmospheric aerosols has been formulated by G. Rozenberg [5,6]. According to this model, the aerosols, as live organisms, have birth, development and death processes. It is known that there are plenty of small particles, so-called Itken particles, the linear sizes of which are less than 0.05 mkm. Due to their small sizes, these particles have no influence on the process of transfer of radial energy (i.e. their optical resilience equals zero). These particles were named "aerosol-creating gases" by Rozenberg. Due to heat movement several dozens of such particles can combine, creating a so-called cluster. Sustainability of clusters is unstable, but in certain conditions they can maintain sustainability and reach linear sizes approximately up to 0.1 mkm. In such cases they become highly stable and continue to grow up to 1 mkm. Rozenberg called this process "transitive". They have great influence on the process of radial energy transmission at this time. Further, they continue growing and become larger particles, their size reaches several mkm and by forced processes (liquid, solid precipitation) or sedimentation they leave the atmosphere rapidly. It is notable that the time of existence of these particles without forcing processes is defined by $8 \cdot 10^5$ sec (about 9 days) by Rozenberg.

K. Tavartkiladze tried to test experimentally Rozenberg's theory both for background and anthropogenic aerosols (including those of marine origin) [7]. He observed the variation of atmospheric aerosols by optical methods after heavy rains in the coastal and high mountain zones of the territory of Ajara. It turned out that after rain reduction of the concentration of aerosols still continued for 2-4 hours, after which the accumulation of background and anthropogenic aerosols started. The accumulation process for the background aerosols lasted for 4 days and for anthropogenic ones – 5 days. Further, rapid reduction of their concentration took place. The results obtained by Tavartkiladze proved Rozenberg's idea about the existence of aerosols for several days.

The influence of atmospheric aerosol particles on the process of transmission of radial energy has been studied very well at present. Research results are presented in the papers of K. Shifrin [8], G. Van De Hyulst [9], V. Zuev [10], D. Deimenjan [11] and others. They prove that the atmospheric aerosols mainly scatter radial energy, but in a number of cases it is observed that they have a weakly expressed feature of selective absorption [3,12-14]. In general, aerosols are characterized by physical features varying in a wide range due to the relation of scattering and the shapes of aerosols, sizes of particles, length of radiation wave, index of environment refraction, etc. For example, the greater the length of radiation wave increase, the greater the reduction of scattering. Therefore, aerosols enhance the dispersion of shortwave solar radiation considerably.

By taking into account spectroscopic data of fraction sample of aerosols, as well as complex observations in natural conditions, Rozenberg [13] showed that atmospheric aerosols have an ability of absorption near the ultraviolet, visible and infrared areas of the spectrum, which is mainly connected with the existence of a submicron fraction in the atmosphere. This fraction is mainly created by soot particles caught by the unabsorbed components, the modal radius of which is about 0. 02 – 0. 03 mkm.

In Abastumani (a high mountain place free from industrial smoke of anthropogenic aerosols), by researching the optical characteristics of background aerosols, G. Rozenberg, I. Lyubtsov and G. Gorchakov [14] showed

the selectivity of aerosol absorption in the ultraviolet area of the spectrum.

The results of studying the saline aerosol sample taken from above the Atlantic Ocean [15] are of great interest. It showed that the existence of dust in the aerosols of marine origin cause an increase of absorption, particularly within the interval of 0.45-0.56 mkm of wave length.

As proven in the references, aerosol absorption is enhanced by an increase of small-dispersed fraction of atmospheric aerosols, as well as by mixture of continental and marine aerosols. Maximum aerosol absorption takes place in the atmosphere above the division zone of the land and the sea.

Vertical distribution of aerosols is also important. It is nearly similar for any underlying surface of the earth. Vertical distribution of aerosol particles in the troposphere is characterized by an exponential decrease, but above the troposphere, the concentration increases, the capacity of which may reach 4-5 km, being observed above any point of the earth. This layer is called "Junge layer".

Having studied the atmospheric aerosols of continental and marine origin in the coastal zone of Ajara, some regularities of atmospheric pollution, unknown before, are presented in the paper and their relation to some parameters determining the climate, namely, to land surface temperature, humidity and wind is shown. The obtained results gave us an opportunity to assess the marine influence on the atmospheric pollution in the coastal zone.

To solve the problem, we used the optical-meteorological method for experimental identification of the level of atmospheric pollution [16], which is based on the regularity of transformation of electromagnetic radiation during its passage through the atmosphere.

The main parameter for assessment of the level of atmospheric pollution is optical resilience [17]. It is known that solar radial energy transforms from the upper boundary of the atmosphere as far as it reaches the earth surface, namely, it is reduced due to dispersion and absorption of radial energy. If we mark the intensity of energy amount in the upper edge of the atmosphere by I_0 and the energy reaching the surface by I, then $\frac{I_0 - I}{I_0}$ is a part of the energy (without measurement), which was transformed during the influence on the atmospheric particles and could not reach the surface. The mentioned value can be called extinction (weakening) function, which identifies the part of the radial energy reduced thoroughly by the atmosphere (it has been studied for the Ajara coastal zone and is presented in [18]). It is accepted [17] that the logarithm of the mentioned part with the Nepper root and the converse mark is an optical resilience of the atmospheric aerosols *t* (extinction coefficient), which identifies quantitatively the reduced value of radial energy. Subordinating to the principle of superposition, it is a summary function, the component parts of which identify the amount of reduced energy by the so-called ideally clean atmosphere t_r, amount of energy reduced by the water vapor t_w, ozone t_u, carbon dioxide t_n and the atmospheric aerosols t_a. Thus:

$$t = t_r + t_w + t_u + t_n + t_a$$

As mentioned above, identification of the optical resilience of atmospheric aerosols in the Ajara coastal zone was conducted by the optical method worked out by K. Tavartkiladze [16]. It is easy to understand that the optical resilience of atmospheric aerosols is directly identified by the amount of aerosols in the atmosphere and their optical features. Hence, it is accepted by the World Meteorological Organization as a parameter identifying the level of atmospheric pollution.

Having conducted multiyear identification of the optical resilience of atmospheric aerosols at the Vakhushti Bagrationi Institute of Geography in the coastal and high mountain zones of Ajara, a special 9-point scale [19] has been created for identification of the level of atmospheric pollution according to the obtained materials.

Table 1 presents numerical values of t_a in the boundaries of each range of the mentioned 9-point system and the names of separate ranges.

Thus, during the years of 2006-2008 in the Ajara coastal zone 430 complex experiments were conducted,

Table 1

9-point system for assessment of the level of atmospheric pollution

№	Range of aerosols optical resilience	Name of the level of atmospheric pollution
1	$\tau_a \leq 0.50$	Ideally clear
2	$0.51 \leq \tau \leq 0.08$	Very clear
3	$0.81 \leq \tau \leq 0.110$	Clear
4	$0.111 \leq \tau \leq 0.130$	Mainly clear
5	$0.131 \leq \tau \leq 0.150$	Normal
6	$0.151 \leq \tau \leq 0.190$	Hardly turbid
7	$0.191 \leq \tau \leq 0.230$	Pretty turbid
8	$0.231 \leq \tau \leq 0.310$	Turbid
9	$\tau \leq 0.311$	Very turbid

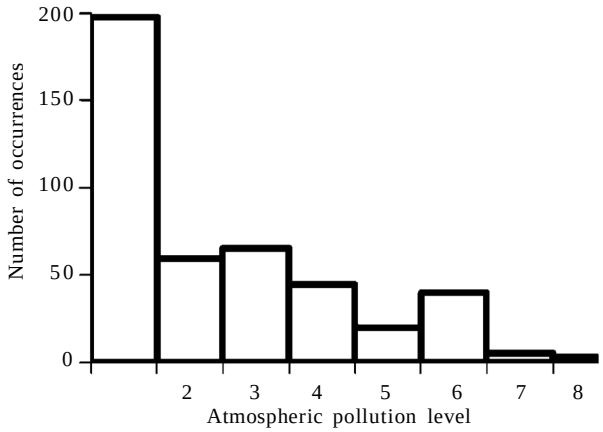

Fig. 1. Histogram of the level of atmospheric pollution for the Ajara coastal zone
(1- Ideally clear; 2- Very clear; 3- Clear; 4- Mainly clear; 5- Normal; 6- Slightly turbid; 7- Rather turbid; 8- Turbid)

where in parallel with the optical resilience of atmospheric aerosols the temperature, water vapor resilience, relative humidity, atmospheric pressure, wind direction and wind speed were measured as well. The general situation of variation of the level of atmospheric pollution in the coastal zone according to the mentioned years is presented in Fig. 1 as a histogram.

On the horizontal axis of the histogram the levels of the atmospheric pollution are marked and on the vertical – the number of cases. As the figure shows, the sky was ideally clear in the coastal zone during the period of the experiment. Nearly the same amount was observed of the very clear, clear and mainly clear atmosphere. Normal atmosphere was observed only 15 times and as the figure shows, turbid and very turbid levels of the atmosphere are rare in the Ajara coastal zone.

If we construct a curve of the resilience of probability distribution according to the histogram, it will look as it is in Fig. 2. The constructed curve identifies the probability corresponding to the value of any optical resilience of atmospheric aerosols.

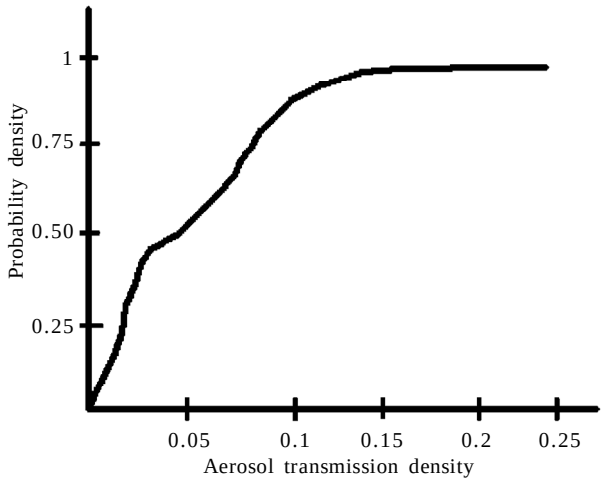

Fig. 2. Distribution of probability of atmospheric pollution in the Ajara coastal zone

According to the above-mentioned figure, we can identify the general situation of atmospheric pollution for the Ajara coastal zone. In order to study the contribution of aerosols of continental and marine origin in the process of formation of the atmospheric pollution and identify the relation among aerosols and some parameter determining the climate, it is necessary to separate the experimental data according to the wind directions.

If we divide the wind direction into three groups, namely, case without wind (calm), east wind and west wind, then in the Ajara coastal zone, where the boundary dividing the sea and the land, stretches mainly from south to the north, during calm the aerosols of continental and marine origin will be presented equally.

Undoubtadely, there will be a prevalance of continental aerosols during the east wind and the prevalance of marine aerosols during the west wind. Having created the three groups, the number of cases was distributed as follows: calm was observed 31 times, continental aerosols made up 106 cases and the remaining 293 cases belong to marine aerosols.

For the distinguished groups the correlation coefficients among the optical resilience of atmospheric aerosols, the temperature, water vapor resilience, relative humidity and wind direction and wind speed were identified and the obtained values together with the corresponding mean values are presented in Table 2.

As shown in Table 2, the aerosols of marine origin prevail in the warm period of the year in the coastal zone. This is indicated by the values of mean temperature and water vapor resilience indicated during east and west winds.

The Table shows first of all that continental aerosols cause less pollution of the atmosphere than marine aerosols. It was probably to be anticipated, and was conditioned by the orographical situation of Ajara (closeness of high mountain zone to the coastal zone). In the coastal zone during east winds relatively clean atmospheric masses are transferred, which are free of anthropogenic aerosols. It is relatively hard to explain the fact that in the case of mixed aerosols the atmosphere is more polluted than in the case of continental or marine aerosols. Doubtless, its reason for statistical analysis is relatively small number of cases (31) during the calm. The regularity of the mentioned phenomenon should be revealed by future studies.

Variations of separate parameters determining the climate are of wide range (the mean square errors are indi-

Table 2.

Mean values and correlation coefficients between the atmospheric pollution and some parameters identifying the climate for continental and marine aerosols

Climate parameters	Mean values			Correlation coefficients (%)		
	Mixed aerosols	Continental aerosols	Marine aerosols	Mixed aerosols	Continental aerosols	Marine aerosols
Optical resilience of aerosols	0.084 (0.053)	0.060 (0.048)	0.073 (0.054)	100	100	100
Temperature (^{0}C)	15.3 (4.4)	12.6 (3.9)	21.1 (6.5)	9	29	42
Water vapor resilience (hp)	13.0 3.3)	9.3 (4.0)	19.9 (7.1)	-15	27	42
Relative humidity (%)	74 (12)	61 (12)	75 (9)	-28	-6	-9
Wind direction	--	South-East	North-West	--	--	--
Wind speed (m/sec.)	--	4.6 (2.8)	3.1 (1.6)	--	-25	40

cated in the brackets). But this situation should not have a great influence on the principle of any regulation, as the dispersion is nearly the same for all parameters and cannot reach even half of the actual value.

Correlation relations of the optical resilience of aerosols and other parameters determining the climate are the lowest for mixed aerosols. Particularly notable is the circumstance that the relation of pollution and temperature and water vapor resilience for marine aerosols is almost twice higher than it is in the case of continental aerosols. This is a very important conclusion and we consider that in future it can be widely used in weather forecasting, as well as during studies of many other atmospheric processes.

It must be also noted that atmospheric pollution is in inverse relation to the variations of relative humidity. We consider it is correct, as the increase of relative humidity causes an increase of aerosols in size thus promoting coagulation and tends to reduce concentration.

It must be noted that other conclusions can be made according to Table 2 as well, but they will have less statistical reliability, because division of data is desirable according to the wind direction to be formed in more groups. And it requires more number of cases.

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რ. სოლომონიძე

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