The level of air pollution in the impact zone of coal-fired power plant (Karaganda City) using the data of geochemical snow survey (Republic of Kazakhstan)

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Abstract. Coal-fired power plants emissions impact the air quality and human health. Of great significance is assessment of solid airborne particles emissions from those plants and distance of their transportation. The article presents the results of air pollution assessment in the zone of coal-fired power plant (Karaganda City) using snow survey. Based on the mass of solid airborne particles deposited in snow, time of their deposition on snow at the distance from 0.5 to 4.5 km a value of dust load has been determined. It is stated that very high level of pollution is observed at the distance from 0.5 to 1 km. there is a trend in decrease of dust burden value with the distance from the stacks of coal-fired power plant that may be conditioned by the particle size and washing out smaller ash particles by ice pellets forming at freezing water vapour in stacks of the coal-fired power plant. Study in composition of solid airborne particles deposited in snow has shown that they mainly contain particulates of underburnt coal, Al-Si-rich spheres, Fe-rich spheres, and coal dust. The content of the particles in samples decreases with the distance from the stacks of the coal-fired power plant.

1.Introduction

The increasing global and local atmospheric pollution is associated with development of power industry to a significant extent. It is known from the domestic and foreign literature [1-14] that construction and operation of fuel-power facilities has led to pollution of all environmental components. In this case, pollution of biosphere is a multi-component, dynamic and complex phenomenon connected with the large number of simultaneous environmental damage: soil-geological, hydrological, geochemical, climatic, and biogeochemical. At high temperature of coal combustion in boilers of fuel-power complexes significant amount of impurities is released into atmosphere as a part of solid particles and gaseous compounds. In all forms they are capable of affecting living organisms including human being [12-14]. Urban atmospheric pollution with thermal power plants emissions is especially harmful to children's health due to intensive metabolic processes in children's organisms, homeostasis immaturity, and immune instability [11, 18]. At present, there is a problem of determining indicators to assess the share of a certain emission source in the general pollution level of the environment. Snow geochemical survey is effectively used by many researchers to assess the conditions of urban environment. Snow is considered to be an extremely accessible and reliable medium for studying air pollution due to its high sorption capacity [3, 14]. Geochemical information on snow allows revealing the dynamics of pollution in winter season, and one sample of the entire snow depth provides the information on pollution rate within the whole period from snow cover formation to sampling time. Mass determination of solid airborne particles deposited in snow is a basis for establishing dust load and permits revealing polluted sites within the period of steady snow cover [5, 12, 18-19]. The study in composition of solid airborne particles deposited in snow contributes to determining mineral and non-mineral technogenic formations as parts of industrial emissions and distinguishing the source of pollution in the enterprise impact zone [12-13]. Investigation of composition is also of crucial significance from the standpoint of human health risk assessment of solid airborne particles. In the work [5] it is shown that long-term impact of technogenic mineral phases composing solid airborne particles is a cause for numerous diseases.

The purpose of the article is 1) to determine the level of snow dust pollution 2) to reveal types of mineral and non-mineral phases in solid airborne particles deposited in snow in the zone of coal-fired power plant impact (Karaganda).

2. Research methods

2.1 Study area

Karaganda City is the largest city in the province and the forth one in Kazakhstan in terms of population (after Almaty, Astana, and Shymkent). During a year in Karaganda the south-west winds prevail, their share within a long term period is 65%. The opposite winds blow in 14% cases, but the frequency of other wind directions does not exceed 7-8%. Karaganda city is administratively divided into two regions: one named after Kazybek bi and Oktyabrskiy. The study area of Oktyabrskiy region is 22.4 thous. hectares in square, which amounts 41.3% of general city square, by 2014 the population of the city was 221.5 thousand people. In the northern part of the city there is one of the largest energy-producing enterprises in Karaganda Oblast – coal-fired power plant. The plant is a major heat and electrical energy producer in the city heat- and energy supply system. The general rated output power of the plant is 592 MW, available one – 418.1 MW. In terms of thermal power – the rated one is equal to 1634 Gcal/h, available is about 1010.3 Gcal/h. The plant operates on Ekibastuz coal, uses fuel oil as a start-up fuel. Ekibastuz coal basin is located in Pavlodar Oblast, Kazakhstan Republic, Ekibastuz city. The disadvantage of this coal consists in the fact that it is high ash (more than 40%) and contains relatively high amount of impurities that decreases thermal effectiveness of coal combustion increasing its transportation cost [14]. Upon the beginning of heating season, due to coal combustion a significant amount of fine dust with technogenic particulates is released into atmosphere.

2.2 Sampling and sample preparation

In January, 2015 snow was sampled in the zone of coal-fired power plant (Karaganda City). In addition, sampling was performed in the residential area located 2.5 km from the coal-fired power plant to the South-West. Sampling was performed using vector network taking into account the principle wind direction (south-west): in the north-east, east, south-east, south, south-west, north-west, and north directions at the distances 0.5; 0.7 km;1.6 km; 2.2; 3.2 and 4,5 km from the stacks. The total amount of samples was 42.

The two areas located 80 km from Karaganda city in the south-east direction were chosen as background sites. In the background sites 4 samples were taken.

Planning sampling points, sampling, and sample preparation were carried out according to the recommendations of RD 52.04.186 № 2932-83 using the methodical guidelines of Institute of Mineralogy, Geochemistry and Crystal Chemistry of Rare Elements, supervision manual over air pollution [14]. According to those specifications, it is necessary to take into account the principle wind direction and stack height when planning the sample procedure, i.e. to select sampling points at the distance calculated as a multiplication of stack height (in our case it is 100 m) by the value from 10 to 40. Snow samples were selected all its depth long with the exception of a 5-sm layer over the ground. The weight of each sample was 15-16 kg. In each sampling the sides and depth of pits were measured the time from stable snow cover formation to snow sampling was fixed (in days). The snow samples were melted in the laboratory condition at room temperature. Snow-melt water was filtered through the paper “Blue ribbon” filter. The solid precipitation obtained after filtration was dried and sieved isolating the fractions of less than 1 mm, then snow solid precipitation was weighed. Solid precipitation consisted of solid airborne particles deposited in snow. After that, the snow solid precipitation was analyzed. In general, 46 snow samples were selected.

2.3.Research methods
The samples of snow solid precipitation were studied in the laboratory of optical diagnostics, International research center “Uranium Geology”, Department of Geoecology and Geochemistry, Tomsk Polytechnic University. Microscopic study of samples was conducted by means of binocular stereoscopic microscope LeicaZN 4D with video and scanning electron microscope (SEM) Hitachi S-3400N with EDS Bruker XFlash 4010. Analysis of composition of snow solid precipitation samples with the subsequent percentage calculation of all mineral and technogenic compounds was carried out in accordance with the patent design [Patent 2229737].

Dust load (P_n, mg·(m^2·day)$^{-1}$) was calculated based on the weight of snow solid precipitation (P_0, mg), square of the snow pit (S, m^2) and the number of days from snow-up day to sampling day (t):

$$P_n = P_o / S \times t \quad (1)$$

In Russia, there is a dust load gradation for detection of pollution rate and morbidity level: less than 250 – low, 251-450 – average, hazardous, 451-850 – high, hazardous, more than 850 – very high, highly hazardous [12, 15].

3. Results and discussion

It was stated that in the zone of Karaganda coal-fired power plant the dust load value changes from 84 to 1145 mg·(m^2·day)$^{-1}$, at the background 47 mg·(m^2·day)$^{-1}$. According to the standard classification [15] the obtained value changes from low to very high pollution rate and from non-hazardous to highly hazardous morbidity rate of population, respectively.

The increased value of dust load is observed at the distance of 0.5 and 0.7 km from the coal-fired power plant in all directions that amounts 864 mg·(m^2·day)$^{-1}$on average, which exceeds the background 18 times and corresponds to very high pollution degree and highly hazardous morbidity rate.

The analysis has shown that the maximum value of dust load is found in the north-east part from the coal-fired power plant, exceeding the background from 3 to 31 times, which can be explained by pollutant transportation in the direction of prevailing wind.

The data obtained for coal-fired plant of Karaganda city are comparable with the calculations [17] of dependencies for fallout intensity of solid airborne particles with the distance from the source in the direction of principle wind. Based on the results of observations the decrease in dust loads up to 9 times occurs with the distance from the coal-fired power plant at the distance 1.6; 2.2; 3.2 and 4.5 km.

The least values of dust load were observed in the south direction from the coal-fired power plant. This value corresponds to low pollution degree and non-hazardous morbidity rate.

In work [17] based on the results of long-term observation over the dust pollution level in the zone of fossil fuel power plant (Tomsk city) operating on coal (~ 40 %) and natural gas (~ 60 %) as fuels, tha value of dust pollution changed from 44 to 115 mg·(m^2·day)$^{-1}$. Besides, it was noted that maximum dust fallouts on snow was observed at the distance of 1.0 km. According to the research, it may be explained by the process of washing out ash small particles with ice pallets formed in water vapour freezing in the thermal plant stack plumes, according to the research [16]. Due to this phenomenon a large part of dust emissions may be deposited at close distances from the plant in winter despite the significant height of stacks.

This phenomenon is likely to be typical for coal-fired power plant in Karaganda city as well that may also explain high values of dust pollution at the distance of 0.5 and 0.7 km from the coal-fired power plant. The increased dust load values may be connected not only with emissions from the studied coal-fired power plant, but also with intake of solid particles due to wind transport from the open coal storage located in the site of the coal-fired power plant or due to the dust formed in coal unloading.

The increased dust load values in the study area are conditioned by the content of different mineral and technogenic particles in solid airborne particles deposited in snow (table1).

Table 1. The value of dust load mg·(m^2·day)$^{-1}$. Content (%) of mineral and technogenic particulates in snow solid precipitation in the North-East direction from the coal-fired power plant, Karaganda city

Distance from TPP, km	Dust load, mg·(m^2·day)$^{-1}$	Pollution level*	Morbidity level*	Mineral particles, %		Technogenic particulates, %				Plant remains, %
				quartz	feldspar	underburnt coal	coal dust	Fe-rich spheres	Al-Si-rich spheres	
0.5	1445	very high	highly hazardous	3	5	32	13	15	20	3
0.7	1186	very high	highly hazardous	9	5	32	13	13	17	3
1.6	398	average	hazardous	10	5	28	12	13	12	5
2.2	269	average	hazardous	10	5	18	10	12	12	5
3.2	227	average	hazardous	22	9	15	10	9	9	5
4.5	165	low	not hazardous	25	9	10	9	7	6	5

Note: * - according to the data [15]

The binocular microscopic analysis of sample composition has shown that snow solid precipitation at the distance of 0.5 and 0.7 km from the coal-fired power plant contains mostly particles typical for emissions of coal-fired power plant, i.e. underburnt coal (8-32 %), Al-Si-rich spheres and Fe-rich spheres (4-20%), coal dust (6-13 %). The least amount of technogenic particles was found in the south direction from the coal-fired power plant (3-9 %). In all samples the mineral part of snow solid precipitation includes mainly quartz (3 - 55 %) as well as feldspar particles (5 - 12 %). The prevalence of technogenic particulates (4-32%) over the mineral ones (3-55%) was revealed in the samples in all directions at the distances 0.5 km; 0.7 km. With the distance from the coal-fired power plant at the distances 1.6; 2.2 km; 3.2 km; 4.5 km the content of mineral particles in samples prevails over that of technogenic particulates (5-18%).

4.Conclusion

Based on the research results obtained it has been determined that high values of dust load are revealed at the distance 0.5 km and 0.7 km from the coal-fired power plant. With the distance from the coal-fired power plant dust load value tends to decrease in all directions. Composition of snow solid precipitation includes different technogenic (coal dust, alumosilicate and metallic microspherules, underburnt coal particles) and mineral (quartz, feldspar) particles. The source of the given particles is suggested to be high-temperature coal combustion at TPP, open coal storage, handling operations. Besides, the possibility of remote pollutant transportation from the plants of Karaganda and its satellites should also be taken into account regarding the principle wind direction.

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