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ASSESSING THE IMPACT OF SUMY CHP ON SOIL

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Abstract. The paper presents assessment of the impact of Sumy CHP when pollutants come into soils with atmospheric precipitation and filtration from the area of the ash and slug dump. Samples of snow were tested for the content of heavy metals and ash particles. Soil samples were tested for the content of heavy metals. The conducted research showed a high degree of soil contamination in the area of Sumy CHP influence.

Keywords: thermal power plant, ash and slug dump, soil, snow cover, heavy metals.

1. Introduction

Nowadays enterprises of thermal power industry are the main sources of environmental pollution in Ukraine. They account for over 30 % of total harmful emissions of industrial enterprises [1]. The growing demand for electricity and heat causes increase in the volume of their production. It leads to a complex negative impact on the environment from power plants and increases the risk for the people living in the area of CHP influence [1–5]. Thermal power plants activities result in the formation of a great amount of wastes belonging to different classes. Slag and ash are rather toxic and this toxicity consists of the toxicity of polycyclic aromatic hydrocarbons (mainly benzo (a)pyrene), heavy metals and unidentified organic toxicants. The concentration of oxides of heavy metals in slag and ash is 2 or 3 times (oreven more) higher than in fuels.

The impact of thermal power plants on the environment depends on the type of fuel. The “cleanest” fuel for power plants is gas. The “dirtiest” fuel is oil shale, peat, bituminous coal and lignite. The largest volume of dust particles and sulfur oxides is formed during the combustion of the fuel. The new energy policy of Ukraine is geared at reducing gas consumption and changing to the use of different types of solid fuels. As a result, thermal power enterprises are increasingly using coal to generate power. It increases the load on the environment. The increasing anthropogenic load on the components of the environment affects their functioning and causes sustainable changes in their structure.

“Sumyteploenerho” Ltd., which also includes Sumy CHP is one of the major air pollutants of Sumy region. The emissions of this company in 2015 amounted to 2.92 ths. tons or 16.69 % of the total emissions in Sumy region [6]. Sumy thermal power plant, which began running in 1957, has been the main source of energy and heat supply. The average capacity of electricity production amounds to 112.988 ths. KW/h, that of heat energy – 723.250 Gcal. The fuels used at thr power plant are coal and natural gas.

The source of soil contamination in the area of Sumy CHP is the aeration zone, where harmful substances from exhaust gases are accumulated on the soil surface and migrate together with precipitation and melting water from the territory of ash and slug dump.

To investigate the soil contamination in the vicinity of Sumy CHP there snow cover in the zone of aeration and the soil in the area of ash and slug dump were analyzed.

2. Experimental part

2.1. Investigation of snow cover in the area of Sumy CHP

Snow cover is a seasonal indicator of the degree of the anthropogenic impact on the environment. Snow has a high sorption capacity and precipitates a significant part of technogenic products from the atmosphere on the terrestrial surface. The long-term monitoring of snow cover makes it possible to detect spatial and temporal distribution features of the polluting elements, identify the pollution hot spots and determine the trends in the environmental quality. The contaminants coming from the enterprises or transport precipitate the soil surface. Together with snow melting these pollutants enter the soil, contaminating it. During snowmelt these pollutants enter the soil and contaminate it.

Among the main reasons for the successful application of snow cover pollution monitoring methods are the following:

– the simplicity of snow cover sampling procedure excluding complex equipment;

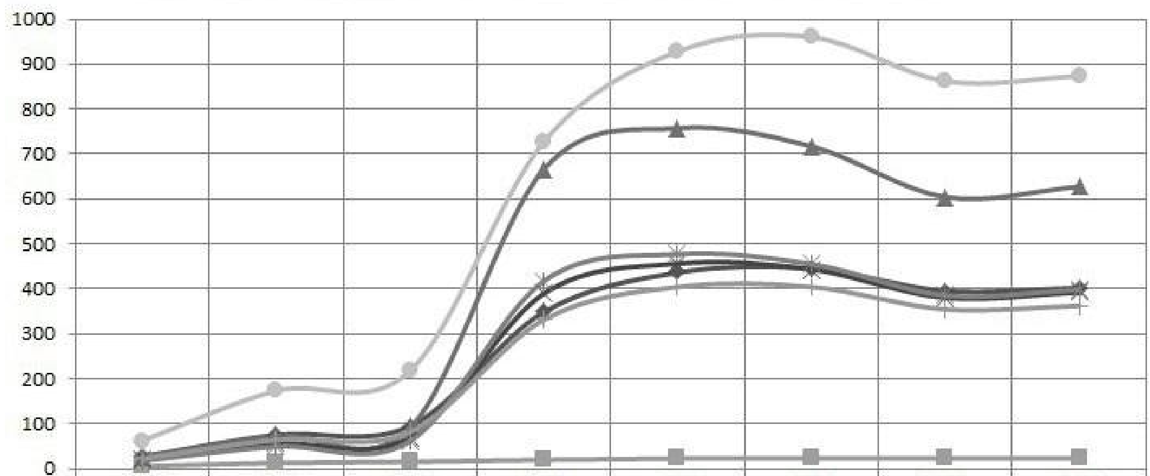
– the possibility of determining quantitive pollution parameters (dry and wet precipitation);

– the simplicity and high reability of measurement methods as concentration of pollutants in snow usually 2 or 3 orders higher than in the air;

– the objective evaluation of dry and wet precipitation in cold seasons [7].

While researching the snow cover, natural and climatic factors were taken into account. The climate of the region influences the dynamics of air pollution. It should be mentioned that wind condition might be an adverse factor.Taking into account the location of the main industrial zones the wind rose vector direction (NW – SE) causes problems in urban environment. The predominant winds are mostly south-eastern and north-western ones, their frequency being 17.5 % and 15 % respectively, and this significantly influences contamination in Sumy. The CHP is located in the north-east area of the city. The lowland topography and poor ventilation of this part of the city enhance the adverse effect of pollution emissionson on the quality of the environment.

According to the emission inventory, Sumy CHP emits 35 air pollutants, including metallic mercury, lead, hexavalent chromium, arsenic, oxides of copper, nickel and zinc.The emissions of heavy metals have increased due to the transition to solid fuels (Fig. 1).



	2006	2007	2008	2009	2010	2012	2014	2016
Lead, kg	27	75	94	348	436	445	395	402
Mercury, kg	5	12	15	19	22	22	22	22
Chrome, kg	25	72	90	666	757	717	604	627
Nikel, kg	20	55	69	389	456	443	380	392
Copper, kg	17	49	61	417	477	455	385	398
Zinc, kg	62	173	217	727	928	960	862	873
Arsenic, kg	22	64	81	331	404	404	354	362

Fig. 1. Dynamics of heavy metals emissions of Sumy CHP

On the basis of average wind direction, observation points for sampling snow cover have been organized. Three snow cover samples were taken from the windward side and another three samples were taken from the leeward side at a distance 0f 500, 1000 and 1500 m from the enterprise (Fig. 2). Reference samples (background samples) were taken at a distance of 10 km from the emission sources. Sampling was carried out in accordance with “Methodical recommendations for assessing the degree of air pollution by metals in settlements by their content in the snow cover and soil” [8]. Snow was taken from the flat surface in February, at the beginning of snowmelt. Snow was sampled from an area of 25x25 cm for the entire thickness of the snow cover without a surface layer (2–3 cm) to prevent soil particles getting into the test. Snow mass samples were collected during one day in all observation points to exclude snow precipitation, because it can reduce the degree of results accuracy.

Meltwater volume amounted to 2.5 liters. The pH determination of samples was carried out by potentiometrically using potentiometer “Checker”. Soluble forms of heavy metals were measured by the atomic emission spectrometry with ICPE 9000 spectrometer. The suspended solids content was determined by gravimetric method.

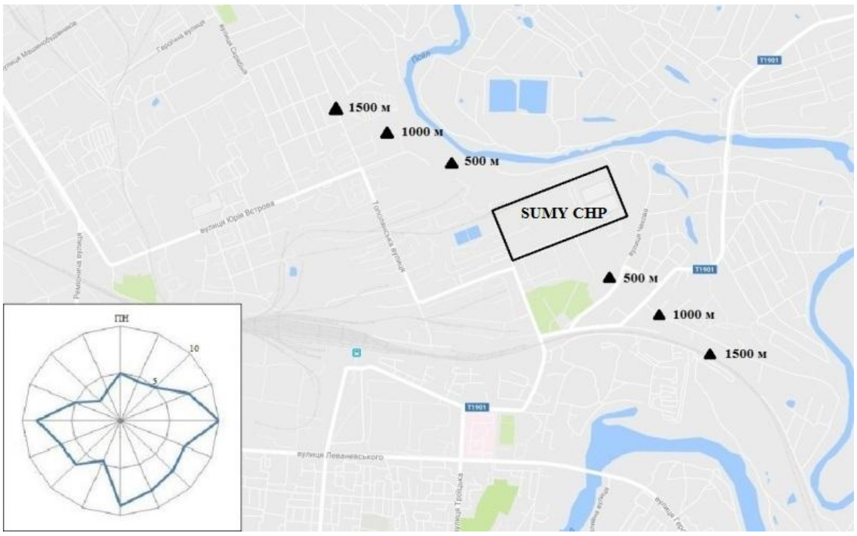


Fig. 2. Location of snow sampling points around Sumy CHP

The obtained data (Tables 1, 2) indicate that the location of Sumy CHP and significant height of pipes (62 m and 100 m) contribute to the "throw-over" pollutants. It explains the maximum concentrations of pollutants within the distance of 1000 m.

Complex assessment of precipitation contamination level on the total pollution index was calculated according to the formula:

$$Z_c = \sum_{i=1}^{n} K_{ci} - (n-1), \qquad (1)$$

where, Z_c – total pollution index of precipitation; K_{ci} – concentration coefficient of the *i-th* pollutant, n – the number of substances.

Concentration coefficient considers toxicity of pollutants against background areas:

$$K_{ci} = C_i / C_{\phi i}, \qquad (2)$$

where, C_i – concentration of the *i-th* pollutant; $C_{\phi i}$ – background concentration of *i-th* pollutant.

Table 1

pH of melt water depending on the distance to Sumy CHP

Wind direction	Background value of pH	pH value at distances. m		
		500	1000	1500
South-east	5.85	6.81	7.31	7.13
North-west		6.65	7.12	6.92

Table 2

The concentration of pollutantsin melt water samples

Substances	Back-ground concentration mg/l	Concentration of pollutants at distances. mg/l					
		Пд-Сх			Пн-Зх		
		500	1000	1500	500	1000	1500
Solid particles	5.8	140	85.1	70	136	66.7	50.4
Cr	0.001	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Ni	0.005	0.012	0.054	0.022	0.012	0.018	0.01
Cu	0.003	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zn	0.01	0.012	0.025	0.014	0.012	0.016	0.007

Table 3

The total rate of snow contamination at different distances from Sumy CHP

Substances	K_{ci}					
	South-east			North-west		
	500	1000	1500	500	1000	1500
Solid particles	24.1	14.7	12.1	23.4	11.5	8.7
Cr	5	5	5	5	5	5
Ni	2.4	10.8	4.4	2.4	3.6	2
Cu	3.3	3.3	3.3	3.3	3.3	3.3
Zn	1.2	2.5	1.4	1.2	1.6	0.7
Z_c	31.1	31.3	21.2	30.4	20.1	14.7

According to the total index of pollution, there is a low level of snow pollution in the vecinity of Sumy CHP.

2.2. Soil research in the area of ash and slug dump of Sumy CHP

Sumy CHP ash and slug dump of is located on the left bank of the Psel river. It is a two-section dump with the a capacity of 195 m^3, the sections size in the plan is 150×178 m each, the total area of 5.3 ha comprises ash and slag mixture by hydro-transportation and wastewater from the chemical water treatment system. Today ash and slug dump is almost full [6].

Slug and ash are toxic. Their toxicity consists of the contence of polyaromatic hydrocarbons (mainly benzo(a)pyrene), heavy metals and unidentified organic toxicants. The concentration of heavy metals oxides in the slug and ash is 2-–3 times (and sometimes more) higher than that of fuel. According to [9] (Table 4) ash contains large amounts of heavy metals. Slug and ash mixture contact with atmospheric water leads to desalination and its conversion into soluble forms and hence to the contamination of soil and groundwater.

The ash dump receives all the wastewater of working site production: chemical water treatment effluents; runoff from fuel oil and reagent areas, farms and coal warehouse; effluents from cooling of bearings, pump and ventilation equipment and blower water boilers. The main contaminants in chemical water treatment wastewater are suspended substances, reagents for regeneration of anionic and cationic filters, regenerate containing ions caught by ion-exchange filters (mostly Ca^{2+}, Mg^{2+}, Fe^{2+}, SO_4^{2-}, CO_3^{2-}, Cl^-) and other reagents form (Cl^-, Na^+). The main pollutants of other effluence categories (except blowing) are suspended solids and oil products.

The site of Sumy CHP is located on the right bank of the Psel river within its 4th floodplain terrace. The upper part of the geological section of this area consists of quaternary cretaceous and paleogene sediments. Quaternary and paleogene formation represent inter-layering of sandy and clay rocks with fractured gaize in a lower surface, and cretaceous system is represented by a loamy and chalky layer, fractured in an overlying bed. As there is no aquiclude, a single free-flow aquifer complex is formed in groundwater on the sufficient depth from the ground – up to 30 m. Water-containing rock is fractured paleocene and cretaceous gaize, which determines the chemical composition of the groundwater. In this area the upper cretaceous covering lies at a depth of 8–22 meters from the ground. Cretace is covered with quaternary alluvial sand and clay sediments of oxbow and floodplain facies (sand, sandy loam and silted loam). Fractured loamy-cretaceous rocks with quaternary sediments form a single free-flow aquifer complex at the groundwater levels of 2.5–7 m above the ground. Directly on the ash dump site, the profile is supplemented with bulk technological formation – a mixture of ash and soils that constitute the embanking. Soil over the waterproof horizon has a heterogeneous composition at the location of dump. It consists of sand from fine to silty, sandy loam with thin layers of silted and sometimes peated loam.

While assessing the environmental hazards of soil contamination we took into account not only the intensity but also the composition of pollutants and especially the presence of elements assigned to the first and second hazard class. Among the pollutants controlled in the research, the first hazard class includes zinc and lead, the second class – nickel, copper and chrome

The determination of gross forms of elements in the soil was carried out by atomic absorption spectrometry. Soil sampling was conducted in accordance with GOST 17.4.4.02-84 [10] within a 100 meter zone of pollution sources influence (Fig. 3).

To assess the transporting of substances from the air and directly from the body of the ash and slug dump, sampling was carried out in the layers on a depth of 0–20 cm and 21–40 cm.. The weight of each sample was not less than 1.5 kg (Fig.4).

Research results are presented in Table 5. The highest concentration of pollutants was in the south-east.

To assess the extent of soil contamination, the total index of chemical pollution by heavy metals was calculated by formula 1. Calculation results are presented in Table 6.

The obtained data show a high level of soil contamination at a depth of 0–20 cm and an average level of pollution at a depth of 21–40 cm.

Table 4

The average content of heavy metals in ash and slag of Sumy CHP mg/kg [4]

№	Type of the sample	Mn	Ni	Co	V	Cr	Mo	Cu	Pb	Zn	Sn
1	Slag	1000	200	40	500	400	4	300	200	80	8
2	Ash	1000	200	20	400	350	2	200	300	300	8

Fig. 3. Soil sampling points in the area of ash and slug dump

Fig. 4. Soil profile

Table 5

The average concentration of contaminants in samples of soil, mg/kg

Horizon	Pollutant				
	Cu	Zn	Pb	Ni	Cr
0–20 см	895	212	31	45	71
21–40 см	612	160	24	28	52
Background concentration	30	60	20	30	50

Table 6

Concentration coefficients and the total rate of soil contamination at soil horizons

Pollutant	K_{ci}		Z_c	
	Upper horizon	Lower horizon	Upper horizon	Lower horizon
Cu	29.83	20.4	37.84	26.24
Zn	3.53	2.67		
Pb	1.,55	1.20		
Ni	1.50	0.93		
Cr	1.42	1.04		

Conclusion

The long-term activity of "Sumiteploenergo" Ltd. caused a change in the state of soils in the aeration zone of the enterprise and in the area of the ash and slug dump. The pollution has disrupted the natural ratio of heavy metals. Copper has the highest coefficients of concentration, and chromium – the smallest. The content of ion-exchange forms of heavy metals in soils decreases as that in the range: Cu> Zn> Pb> Ni> Cr. The level of snow cover contamination at average values Zc is low, in soils of the ash and slug dump area for the upper horizon it is high and for the lower one it is average what points out the complex impact on soils.

References

[1] Rykhter L. A.: Okhrana vodnoho y vozdushnoho basseina ot vybrosov TES. Enerhoyzdat, Moskva. 1981.

[2] Krupskaya, L. T., Starozhy`lov V. T.: Geoekologiya landshaftov v zone vliyaniya teploelektrostancii`: monografiya. DVGU, Vlady`vostok, 2009.

[3] Mylenka, M. M.: Aerotekhnohenne zabrudnennia dovkillia vykydamy Burshtynskoi teploelektrostantsii. Suchasni ekolohichni problemy ta molod-IV: mater. mizhvuz. nauk. konf., 25–26 lystopada 2008 r. Zaporizhzhia, 2008, Vol. 5.

[4] Beliavskyi H. A., Varlamov H. B., Hetman V. V.: Otsenka vozdeistvyia obektov enerhetyky na okruzhaiushchuiu sredu. KhHAHKh, Kharkov, 2002.

[5] Prybylova V. M., Zhemerova V. O., Reshetov I. K.: Osoblyvosti nakopychennia zabrudniuvachiv v zoni vplyvu Zmiievskoi TES. Visnyk Kharkivskoho natsionalnoho universytetu im. V. N. Karazina: Heolohiia-heohrafiia-ekolohiia, 2010, No. 882, 62.

[6] Dopovid pro stan navkolyshnoho pryrodnoho seredovyshcha v Sumskii oblasti u 2015 rotsi [internet resource]. – http://www.menr.gov.ua/dopovidi/regionalni/5560-rehionalni-dopovidi-pro-stan-navkolyshnoho-pryrodnoho -seredovyshcha-u-2015-rotsi

[7] Demydenko H. A. Vlyianye zolootvala Krasnoiarskoi TETs-1 na snezhnyi pokrov prylehaiushchei terrytoryy. Vestnyk KrasHAU, 2015, No. 9, 88.

[8] MR 5174-90. Metodycheskye rekomendatsyi po otsenke stepeny zahriaznenyia atmosfernoho vozdukha naselennykh punktov metallamy po ykh soderzhanyiu v snezhnom pokrove y pochve. M., 1990

[9] Voitiuk Iu.Iu. Zakonomirnosti rozpodilu vazhkykh metaliv v ob’iektakh navkolyshnoho seredovyshcha m. Sumy. Visnyk Dnipropetrovskoho universytetu. Heolohiia, heohrafiia. No. 22, C. 2, 18.

[10] Yzmerenye massovoi doly elementov Cd, So, Sh, Su, Mn, R, V v probakh pochv, hruntov y donnikh otlozhenyi: MetodykaM03-07-2009 PNDF16.1:2:2.2.63-09 - SPb. 2009. 3 c. [internet resource]: www.lumex.ru.