Multi-component environmental impact assessment of a thermal power station

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Abstract. The production of electricity at thermal power plants using fossil fuels involves the use of such material resources, most of which are converted into waste that is released into the environment. Hrazdan Thermal Power Station is the largest power plant in Armenia, built and put into operation in the late 1960s. During the study, a comparative analysis of the concentration of some chemical elements in soil samples, including the Hrazdan Thermal Power Plant and the Hrazdan Cement Plant, was carried out. The analysis showed significant differences depending on the sampling location and season. This may be due not only to snow cover but also to the start of spring fieldwork and the application of fertilizers and pesticides to agricultural land, as well as the active period of power plant operation. Therefore, when using multi-criteria methods to assess the environmental impact of different types of power plants, it is necessary to consider the soil pollution coefficient as a separate correction factor.

1 Introduction

An indispensable factor in the successful development of a modern industrial complex is the use of electricity. In countries with limited energy resources, the intensive use of thermal power stations (TPS) is the focus. The construction and operation of energy plants have a significant impact on the environment and to ensure its protection, it is necessary to consider the conditions of sustainable development. The technology of generating electricity in TPS using organic fuels means that almost all of the material resources used and most of the fuel energy is converted into waste that is released into the environment. The technogenic impact of TPS on the environment is expressed in atmospheric pollution, the discharge of polluted water into water basins, waste disposal, especially in coal-fired power plants, and noise, thermal and electromagnetic pollution [1].

The Hrazdan Thermal Power Station (HTPS) is the largest power plant in Armenia, located near the city of Hrazdan. When the HTPS was designed and built, the question of its environmental impact was not so urgent. It was built and commissioned in the late 1960s. In the country's domestic market, HTPS offsets the resulting increase in energy

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consumption. For internal consumption, the plant produces electricity only when there is a shortage in the Armenian energy system (mainly in the autumn-winter period and during the shutdown of the nuclear power station). Actually, for Armenia, the aim was to provide industry and the population with a cheap source of energy with high efficiency, low losses, and long-term trouble-free operation. At the same time, HTPS is extremely important for exporting electricity. Therefore, to assess the environmental impact of HTPS, it is necessary first to understand which factors have the greatest impact on the environment. The basic principles of multi-criteria decision-making (MCDA) [2] are proposed to investigate and assess the impact of different types of power plants on nature ecology. This approach allows for a comparative assessment of different systems. Five criteria were used to assess the environmental impact: intensity of CO_2 emissions from energy production (K_1), radiation impact on the environment (K_2), solid waste from electricity production (K_3), specific area for the entire life cycle of the power plant (K_4) and water use in electricity production (K_5) [3]. After summarizing all these criteria ($\sum_{i=1}^{n} K_i$) for each of the main energy sources in Armenia, a comparative series of environmental impacts was obtained for them, where coal-fired TPS have the worst indicator according to [4]

nuclear power station (0.818) < hydropower station (0.791) < natural gas thermal power station (0.750) < coal-fired thermal power station (0.231).

Based on the comparative series above in our studies, we set out to assess soil contamination around HTPS.

2 Object and methods of research

The experimental study determined the concentrations of trace elements (TE) such as vanadium (V), chromium (Cr), nickel (Ni), and ultra-trace elements (UTE) such as copper (Cu) and zinc (Zn) in soil samples collected during the agricultural year: autumn 2021, winter 2021/22, spring 2022 and summer 2022 from the Hrazdan region (three sites) of Armenia. The geographical coordinates of each sampling site are given in Table 1.

Table 1. Geographical coordinates of the sampling sites.

Sampling sites		North	West
Hrazdan region	point 1	40°33'04.6"	44°44'41.9"
	point 2	40°33'16.4"	44°44'42.0"
	point 3	40°33'22.2"	44°44'48.6"

The soil was located southwest of the industrial zone, including the Hrazdan thermal power plant and the Hrazdan cement plant. The soils were semi-desert mountain gray, formed at 850-1350 m altitudes above sea level. Soil samples were collected in dry weather using the envelope method to a depth of up to 20 cm with nonmetallic tools, considering anthropogenic loading and regional wind rose [5]. The samples were placed in dark glass containers and transported at +4°C for 24 hours for instrumental measurements in the laboratory [6]. Elements analysis of all soil samples was carried out under direct X-ray irradiation using a Termo Scientific™ Niton™ X-ray fluorescence analyzer [7]. The calculation of mean concentrations of elements and analysis of variances were performed to estimate statistically significant differences between groups of samples.

3 Results and discussion

Natural conditions significantly impact the chemical composition of the soil cover, changing its qualitative and quantitative properties [8,9]. The study of seasonal changes in the concentrations of TE and UTE in the soil cover and determining the factors that change their concentration, chemical activity, bioavailability and toxicity are important for solving some environmental problems [10, 11,12]. According to the research approach, during the entire sowing period from autumn 2021 to summer 2022, the concentration changes of V, Cr, and Ni of the TE group, as well as Cu and Zn of the UTE group were investigated (Fig.1).

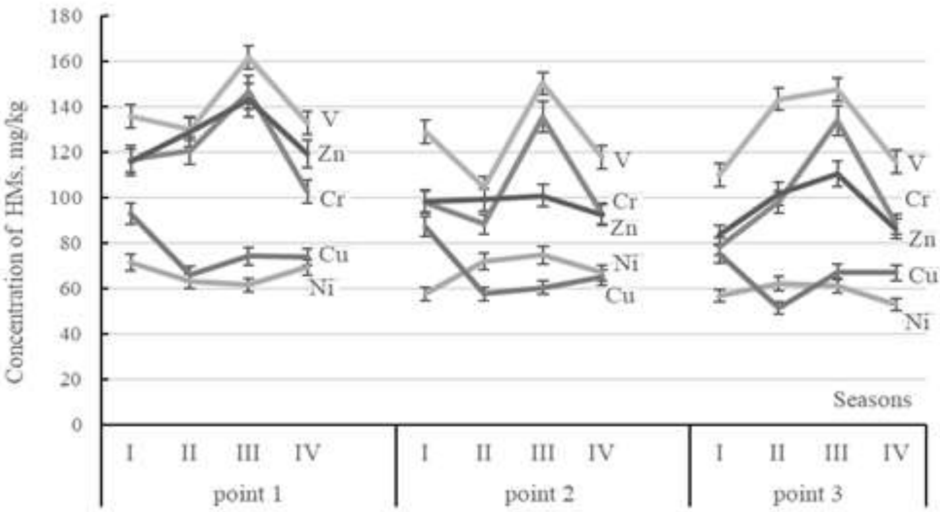

Fig. 1. Seasonal concentration changes of some chemical elements in soil samples near the HTPS.

Therefore, at soil sampling point 1, which was as far away as possible from the possible source of pollution, the measurements of the concentration of chemical elements in the fall soil samples showed two main groups. In the first group, elements with relatively high concentrations in soil samples are V (135.9 mg/kg), Zn (115.9 mg/kg), and Cr (117.2 mg/kg). The second group contains the studied chemical elements with relatively low concentrations in soil samples: Cu (92.8 mg/kg), and Ni (71.4 mg/kg). Seasonal variations persisted throughout the experimental cycle and did not show significant changes. In winter, soil samples showed a significant decrease in concentrations, except for Zn and Cr. However, the average concentration of all elements in the soil samples from point 1 increased by up to 30% in the spring soil samples. The situation was completely different for their accumulation in the autumn sampling period, where a clear decrease in concentration was observed in all samples. In the comparative analysis of points 2 and 3, the dynamics of the comparative series of concentration changes of the chemical elements studied in soil samples was maintained, but with a slight decreasing effect. Table 2 shows the correlations between chemicals in soil samples at all sites during the experimental run. Positive and negative correlations were found with varying degrees of significance. It should be noted that the results of the correlation analysis may be influenced by similarity in soil type.

Table 2. Coefficient for correlation between chemical elements in soil samples taken at different sites and seasons

point 1	V	Cr	Ni	Cu	Zn
V	1				
Cr	0.882	1			
Ni	-0.559	-0.759	1		
Cu	0.007	-0.113	0.727	1	
Zn	0.802	0.887	-0.943	-0.536	1
point 2	**V**	**Cr**	**Ni**	**Cu**	**Zn**
V	1				
Cr	0.935	1			
Ni	0.130	0.468	1		
Cu	0.152	-0.189	-0.950	1	
Zn	0.438	0.555	0.299	-0.048	1
point 3	**V**	**Cr**	**Ni**	**Cu**	**Zn**
V	1				
Cr	0.844	1			
Ni	0.857	0.598	1		
Cu	-0.658	-0.194	-0.568	1	
Zn	0.980	0.928	0.827	-0.495	1

At point 1, a strong direct positive relationship was observed between Cr and V, Zn and V, Cr. In soil, there was a strong correlation between elements such as Cu and Ni. For this soil sampling point, there was a direct strong negative correlation between Zn and Ni, a strong negative correlation between Ni and V, Cr, Zn and Cu. At sampling point 2 there was a direct strong positive correlation between Cr and V, but at the same time a direct strong negative correlation between Cu and Ni. Furthermore, at sampling point 3, a direct strong positive relationship was observed between Zn and V, Cr, and Ni. Cr and V, Ni and V, Cr. In the sampling soil, there was a strong moderate negative correlation between elements such as Cu and V, Ni, Zn, and Cu.

4 Conclusion

The basis for the development of environmental protection measures is material on the natural and man-made conditions of the territories where thermal power stations are located, obtained as part of engineering and environmental surveys. During the study, a comparative analysis of the concentration of some chemical elements was carried out in soil samples, including the Hrazdan Thermal Power Station and the Hrazdan Cement Plant. The analysis showed significant differences depending on the sampling locations and seasons. The concentrations of the elements studied had statistically significant differences, increasing during the summer season, with the highest accumulation at the point 1 sites. In winter, low concentrations of elements were found at all soil sampling sites. This may be related not only to snow cover but also to the beginning of fieldwork in spring and the application of fertilizers and pesticides to agricultural land, as well as the active working period of HTPS. During the subsequent summer sampling, a significant decrease in the concentration of chemical elements was observed in the materials studied. It is necessary to take into account the soil pollution factor when using multi-criteria methods of assessment of the environmental impact of different types of power stations.

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