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Monitoring of benzo[a]pyrene content in soils under the effect of long-term technogenic poluttion

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ABSTRACT

The aim of the current work was to study the main tendencies in the accumulation and distribution of benzo[a]pyrene in soils of the affected zone of the Novocherkassk regional power plant. Studies were conducted on the soils of monitoring plots subjected to Novocherkassk regional power plant emissions. Monitoring plots were established at different distances from the Novocherkassk regional power plant (1.0–20.0 km). Regularities in the accumulation and distribution of benzo[a]pyrene in chernozemic, meadow-chernozemic, and alluvial soils under the effect of aerotechnogenic emissions from the Novocherkassk regional power plant have been revealed on the basis of long-term monitoring studies (from 2002 to 2011). The tendencies in the distribution and accumulation of BaP in the studied soils coincided during the 10 years of monitoring studies. It has been found the 5-km zone to the northwest from the power station, which coincides with the predominant wind direction, is most subjected to contamination by benzo[a]pyrene, with the maximum accumulation at a distance of about 1.6 km from the source. Dynamics of pollutant accumulation in soils depends on number of Novocherkassk regional power plant emissions. The content of benzo[a]pyrene in the soil is an indicator of the technogenic load impact on the areas, for which the combustion products of hydrocarbon fuel are the major pollutants. A gradual decrease of the pollutant content in the soils was revealed during the period from 2002 to 2011. It explained by the significant decrease in the volume of pollutant emissions from the plant and the self-purification capacity of soils and mechanisms of benzo[a]pyrene degradation.

1. Introduction

The assessment of the environmental status of soils as a central link of ecosystems is an essential parameter in the system of environmental monitoring. The soil is the central ecosystem component depositing pollutants. The regular observation of the accumulation and distribution of anthropogenic pollutants in the soil is an essential problem of soil science. The improvement of the state of the environment under pollution is possible only after long-term monitoring studies for revealing the character and nature of pollution, the composition of pollutants, their diversity, and mechanisms for the accumulation and transformation of pollutants in the studied biogeocenosis (Cristale et al., 2012; Tobiszewski and Namiesnik, 2012). The most optimal methods for the restoration of the area subjected to technogenic contamination can be found only on the basis of large-scale monitoring studies and the investigation of the main tendencies in the accumulation of pollutants (Antizar-Ladislao et al., 2006; Augusto et al., 2013; Minkina et al., 2012; Oros et al., 2007).

Polycyclic aromatic hydrocarbons (PAHs) are among the most hazardous and widely distributed soil pollutants characterized by increased toxicity and carcinogenicity. The content of PAHs in all natural objects is subject to mandatory control throughout the world, which is regulated by legislations of different countries (GOST 17.4.1.02.-83, 2004; GOST 14.4.3.06-86, 1986; Jian, 2004; Wenzl et al., 2006).

Benzo[a]pyrene (BaP) is most frequently considered as the main marker of soil contamination by PAHs, because this is the most prevalent PAH characterized by a very high persistence in environmental objects and elevated carcinogenicity and mutagenicity (Jian, 2004). BaP is a compound of hazard class 1; it is included in the group of superecotoxicants, and its content in all objects of the ecosystem is subject of mandatory control (Tobiszewski and Namiesnik, 2012; Wenzl et al., 2006). In Russia, the maximum permissible concentration (MPC) of BaP is 0.02 mg/kg for all soils; in other countries, this value varies in the range of 0.1–2.7 mg/kg.

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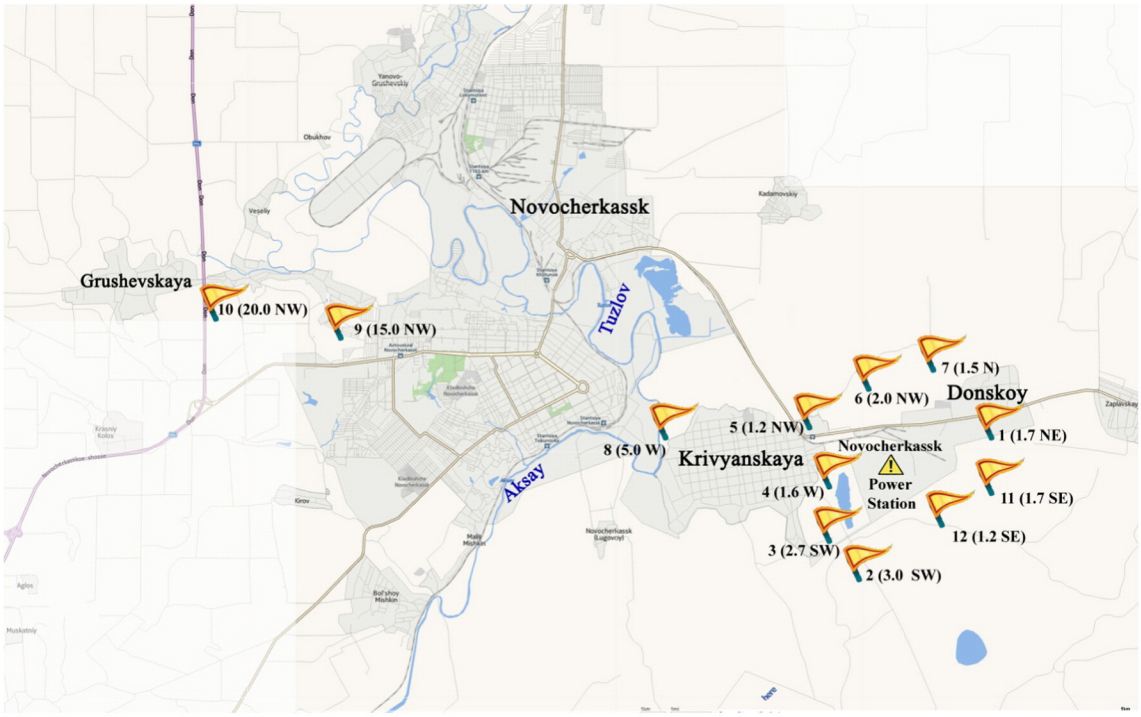

Fig. 1. Schematic map of monitoring plots in the zone affected by the NRPP.

Plot No.	The direction and distance from NRPP:
1	1 km on the northeast;
2	3 km on the southwest;
3	2,7 km on the southwest;
4	1,6 km on the northwest;
5	1,2 km on the northwest;
6	2,0 km on the northwest;
7	1,5 km to the north;
8	5 km on the northwest;
9	15 km on the northwest.
10	20 km on the northwest.

The monitoring studies of environmental pollution with PAHs have been performed in many countries over tens of years. A number of works well with the study of the state of the areas subjected to technogenic contamination with PAHs (Callén et al., 2013; Pereira et al., 2013; Singh et al., 2013; Sushkova et al., 2015a,b; Witter et al., 2014; Xing-hong' et al., 2006; Yam and Leung, 2013; Zhu et al., 2015). The contamination is of technogenic origin in all the cases.

Active sources of environmental pollution with PAHs include enterprises of energy industries, especially great thermal stations (Anon., 2002; Sushkova et al., 2015a,b; Witter et al., 2014; Yam and Leung, 2013). The Novocherkassk regional power plant (NRPP) is one of the greatest thermal power stations not only in Russia, but also in Europe. This is an enterprise of hazard class 1, which was set in operation in 1965–1971. At present, it includes eight working blocks and is the main source of electrical energy in Rostov oblast. Coal and natural gas are the major fuel types for the station. The height of the first chimneystack is 185 m; the three other stacks are 250 m high.

Ecological monitoring performed since 2000 showed that the NRPP is the main pollution source of the atmospheric air not only in the city of Novocherkassk, but also in the entire Rostov oblast, and makes the major contribution to the environmental pollution in this region. The aim of the current work was to study the main tendencies in the accumulation and distribution of BaP in soils of the affected zone of the NRPP.

2. Materials and methods

The main objects of study were soils in the affected zone of the NRPP. The satellite images of the NRPP and its affected zone, as well as the locations of monitoring plots, are given in Fig. 1. They coincided with the air sampling sites for the ecological certificate of the plant (plots 1, 2, 3, 5, 6, 7) (Fig. 1). The most attention was paid to the main wind direction from the contamination source to the northwest through the residential areas of Novocherkassk (zones 4, 8, 9, 10) (Table 1). The monitoring plots were located on virgin lands or fallow areas. The soil cover in the region under study consisted of ordinary chernozems, meadow-chernozemic soils, and alluvial meadow soils.

Most of the area in the affected zone of the NRPP is occupied by calcareous ordinary chernozem (Co); meadow-chernozemic soil (MCS) (plot 3SW) and alluvial soil (AS) also occur in the Tuzlov River floodplain of the studied zone (Table 2).

The Co and MCS have thick humus horizons (70–100 cm), relatively high content of humus (4.1–5.0%) and high cation exchange capacity (CEC) (31.2–47.6 cmol(+)/kg), including a high content of exchangeable calcium (76–90% of total exchangeable cations), and neutral or weakly alkaline reaction (pH_{water} 7.4–7.7) (GOST 26423–85, 1985). According to particle size distribution, they belong to heavy loamy and light clayey varieties developed on calcareous loess-like rocks. The climatic index of biological productivity (Bc) is 90–100 under natural conditions and 170–175 under optimum wetting conditions. The sufficient

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