VSB Technical University of Ostrava (VSB-TUO) and Central Mining Institute in Katowice (GIG) cooperation on heap research

Współpraca VSB Politechniki w Ostrawie (VSB-TUO) i Głównego Instytutu Górnictwa w Katowicach (GIG) w zakresie badań hałd

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Abstract: The aim of the work was a pilot cooperation of the VŠB-Technical University of Ostrava (VŠB-TUO) and Central Mining Institute Katowice (GIG) on a common problem of emissions of gases and dust particles from dumps and piles after mining and metallurgical activities. These heaps are the remains of intensive mining and metallurgical activities in the Czech-Polish border area. The main content of the work was to quantify the contents of heavy metals and polycyclic aromatic hydrocarbons in emissions from selected heaps, one on the Czech and one on the Polish side of the border. The result of this work is a model modeling of the secondary resuspension of dust particles in dependence on climatic conditions and estimation of ecological risk of emissions from thermally active dumps.

Treść: Celem projektu była pilotażowa współpraca pomiędzy Uniwersytetem Technicznym VŠB w Ostrawie (VŠB-TUO) i Głównym Instytutem Górnictwa w Katowicach dotycząca wspólnego problemu emisji gazów oraz cząstkek pyłów pochodzących z hałd oraz zwałów powstałych w wyniku górniczej oraz hutniczej działalności. Badaniami objęto hałdy powstałe w wyniku intensywnej działalności górniczej i hutniczej w czesko-polskim pasie przygranicznym. Główne założenie realizowanej pracy polegało na ilościowym określeniu zawartości/stężeń metali ciężkich oraz wielopierścieniowych węglowodorów aromatycznych w emitowanych gazach pochodzących z wcześniej wytypowanych hałd znajdujących się po obu stronach granicy na terenie Czech oraz Polski. Rezultatem prac było wykonanie modelu przedstawiającego rozprzestrzenienie wtórnej zawiesiny cząstek pyłu w zależności od warunków klimatycznych i wielkości emisji oraz oszacowanie ryzyka ekologicznego w związku z emisją gazów pochodzących z termalnie aktywnych hałd.

Keywords:

heap, emissions, ecological risk, secondary resuspension

Słowa kluczowe:

hałda, emisja, ryzyko ekologiczne, wtórna zawiesina

1. Subject

The aim of the research was to quantify emissions of heavy metals and polycyclic aromatic hydrocarbons from dumps and hunger for mining and metallurgical activities. These heaps are the remains of intensive mining and metallurgical activities in the Ostrava-Karviná district and mining districts on the Polish side of the border. Very often not only mechanical but also chemical changes of deposited materials occur on these piles. Often, the stored material also ignites and burns. Examples include the heap of Emma on the Czech side, or the dump of Wrzosy on the Polish side of the border.

The resulting and subsequently sedimenting dust particles from the surface of these piles and dumps with wind erosion, movement of people and technology as well as the extraction of the piles reach air and may contribute to the deteriorated air quality in the surrounding environment (airborne dust, carcinogenic substances). This phenomenon can contribute significantly to the deterioration of the air quality in the region. The greater the risk may be if polyaromatic hydrocarbons (PAHs) are produced on the smallest dust particles (PM_{10} and smaller) resulting from the combustion of thermally active piles.

The current issue of air quality in the region connected with dust and gaseous emissions from dumps and hunger for mining and metallurgical activities has been the subject of several joint Czech-Polish projects. This was the project "Air Quality Information System in the Poland-Czech Border

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Region in the Silesian and Moravian-Silesian Regions” (CZ.3.22 / 1.2.00 / 09.01610, Air Silesia). However, this did not address the issue of dust and gaseous emissions from piles directly. Two other projects, however, already represented a breakthrough in the solution of this issue and their results and outputs brought very interesting findings. It was the project Evaluation of concentrations of PAH and heavy metals on the surface of dumps and in the vicinity of industrial enterprises (CZ.3.22 / 1.2.00 / 12.03398, PAHMET) and the subsequent TERDUMP project Cooperation of VŠB-TUO / GIG Katowice border (CZ.11.4.120 / 0.0 / 0.0 / 15_006 / 0000074). Given that the problems associated with emissions of heaps were funded under the European programs Operational Program Cross-border Cooperation (OPPS) and subsequently Interreg V-A Czech Republic - Poland. Both projects were held by the VSB - Technical University of Ostrava (VSB-TUO), the Polish partner was Central Mining Institute (hereinafter referred to as CMI).

The original exploration work in the dump area focused on suspended particle emissions focused mainly on the EIA processes of various business plans addressing the use of materials stored in the dump body for construction purposes. These works were only carried out in a small number of locations and were far from a comprehensive study. However, it was not possible to deduce seriously the overall impact of dumps on air quality in this region from such a small and tendency-oriented number of data.

The second area related to air quality, which was focused on earlier surveys, was the emission of gaseous substances from thermally active dumps. However, the results obtained are burdened with unacceptably high uncertainties, which preclude their use for the design of regulations for further use of dump.

The main shortcoming of the existing evaluations is the absence of information on the content of heavy metals and polycyclic aromatic hydrocarbons in air emissions. Impact of dumps on the air pollution situation and contribution to possible environmental risks of these pollutants could not be reliably assessed from the measured values.

Both PAHMET and TERDUMP projects therefore focused on the immission impacts of waste dumps associated with emissions of heavy metals and polycyclic aromatic hydrocarbons. In addition to the determination of toxic metals, the research also included the determination of the mineral phases by X-ray diffraction in the rolling material. This parameter is very related to its character. All analyzes and determination of inorganic and organic parameters were concentrated on PM10 and smaller particles. These are considered the most risky for human health (ČSN EN 15445: 2009, AZ GEO, s.r.o., 2012, Kaličáková i in. 2013).

2. Selection of locations

Ten localities in the Czech Republic and ten localities in the Polish side of the border were selected for the PAHMET project. The TERDUMP project then focused only on thermally active heaps, three on the Czech side and three on the Polish side of the border.

The pilot study in both projects was then carried out at one locality in the Czech Republic and one in Poland, namely the EMA heap and the Wrzosy site KWK “Rydułtowy Anna” (Pszów, Poland).

2.1. EMA heap

The EMA heap is the oldest mining dump in Ostrava. It is a conical heap (peak about 315 m above sea level), which is currently a natural monument administered by the state enterprise DIAMO. In fact, it is a complex of dump closed mine Ema / Lucie, Trinity and Petr Bezruč (Terezie). The dump contains heap and fly ash and is still thermally active. The temperature inside the heap body reaches up to 1200° C. Pilot samples were taken from 4 metal collection points and two for emission analysis of burning products.

2.2. Wrzosy KWK „Rydułtowy Anna”(Pszów) location

Heap of Wrzosy is managed by KWK ‚Rydułtowy”. Samples were taken from 16 sampling sites for the study.

3. Methods and applied procedures

In a pilot study, a complex chemical and mineralogical description of the surface layer of the heap was performed on both heaps, including the chemical composition of the inorganic and organic phases. Subsequently, a thermovision survey was carried out and gas and dust emissions were

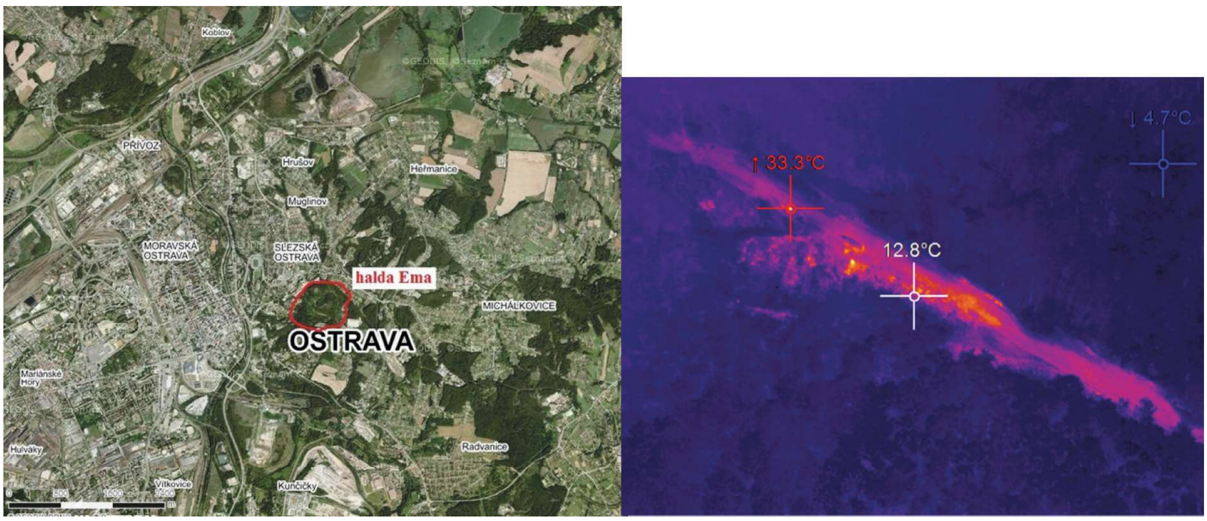


Fig. 1. Localization of the EMA heap and its thermal image
Rys. 1. Lokalizacja hałdy EMA i wyniki pomiarów termicznych

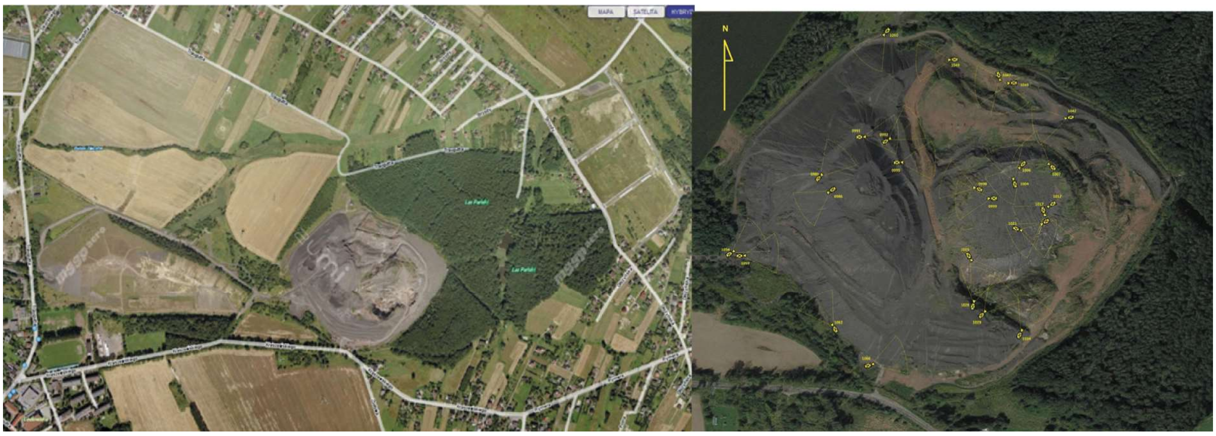


Fig. 2. "Wrzosy" heap localization and sampling sites
Rys. 2. Lokalizacja hałdy "Wrzosy" oraz miejsc prowadzonych badań

collected from the detected hot spots (natural vents) for the determination of PAHs. Both partners, VŠB-TUO and GIG Katowice, have research teams with long-term experience and above-standard laboratories (Dombek 2012).

3.1. Methodology of sampling

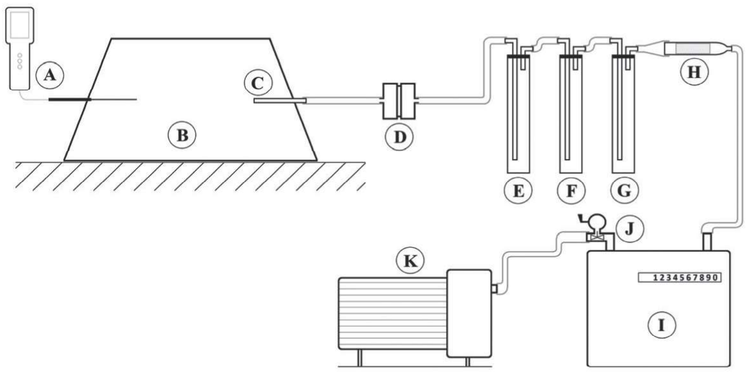
The sampling method used for dust emission analysis was based on US EPA AP-42 standards (1985). One total sample was obtained from 6 partial (primary) samples, each taken from an area of 1 m 2 at a maximum depth of 2.5 cm. Subsequently, the sample thus obtained was conditioned after obtaining the PM10 fraction for the determination of heavy metals and PAH. Sampling of gaseous and dust emissions from natural vents was performed using the assembled apparatus, which is shown in Fig. 3.

3.2. Methods of analysis

The heavy metal content in the PM_{10} dust fraction was determined after total mineralization by the king's bow with an analytical tip on ICP-OES. Content of 16 representatives of PAH (according to U.S.EPA - naphthalene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo (a) anthracene, chrysene, benzo (b) fluoranthene, benzo (k) fluoranthene, benzo (a) pyrene, dibenzo (a, h) anthracene, benzo (g, h, i) perylene, indeno (1,2,3-cd) pyrene) was determined after extraction of PM_{10} dust particles on ASE and column purification by SPE (solid-phase extraction), using high performance liquid chromatography (HPLC) with a fluorescent detector. Determination of PAHs in emissions from thermally active dumps after capture on PUF and subsequent extraction was also performed by the same HPLC procedure. Mineralogical analysis was performed at both workplaces on Bruker X-ray diffractometer.

4. Modelling

The aim of mathematical modeling was to evaluate the effect of emissions of heavy metals and polycyclic aromatic hydrocarbons produced by heaps on air quality. For calculation of air pollution contributions of evaluated substances by model SYMOS'97, for calculation of average annual suspended particulate emissions, which were input for modeling, the method of U.S. Pat. EPA (1984): Chapter 11.9, Western Surface Coal Mining. Since the resuspension occurs only from a certain wind speed, the distribution of suspended particulate emissions over the year has been calculated based on U.S. Pat. EPA (1984): Chapter 13.2.5, Industrial Wind Erosion.



A - Temperature measurement of heap body; B - Heap; C – Glass probe; D - Cooler; E,F, G - Impingers; H - PUF sorbent; I - Membrane gas meter; J - Flow controller; K - Gas pump

Fig. 3. Sampling apparatus for determination of combustion emissions
Rys. 3. Aparatura do oznaczenia emisji pochodzącej ze spalania

The approach to take into account frost days was taken from the methodology of CHMI, VAV / 740/2/02, DP 2: 2. Taking into account the resuspension of particles from the Earth's surface. Climatic data (wind rose) necessary for modeling using SYMOS´97 were supplied by Czech Hydrometeorological Institute (CHMI) in Ostrava-Poruba.

The assessment of direct and indirect effects of thermally active waste dumps associated with air pollution consisted of estimation of PAHs emissions, estimation of air pollution contributions of PAHs and screening of health risks.

5. Results

5.1. Mineralogical analysis

The following minerals were found in PM10 dust samples collected at pilot sites:

– basic: silicon SiO2, clay minerals (kaolinite, muscovite, illit, chlorites, potassium feldspar (orthoclase, microcline, sodium-calcium feldspar and amorphous substance)
– accessories: calcite, dolomite, ankerite, siderite, goethite, hematite, magnetite, gypsum, jarosit, alumite, halite, brucite, pyrite, mullite, montmorillonite and mixed structures of ilite-smectite and chlorite-smectite.

An example of a diffraction pattern of a PM10 dust sample from a Polish plant and a qualitative interpretation is shown in Figure 5. However, quantitative calculations using the Toper software from Bruker for a PM10 sample from a Czech plant are shown in Figure 4.

5.2. Modelling PM10, metals and B[a]P

With regard to the total immission concentration and taking into account the fact that the highest effects occur in a period of low total immission concentrations (windy weather with good dispersion conditions), the effect of both studied heaps on average annual PM10 suspended particulate concentrations can be evaluated as relatively minor and local. first hundreds of meters). The effect of both studied heaps on average annual concentrations of arsenic and benzo (a) pyrene is insignificant. The impact of the main sources of these pollutants in the region (individual heating of family houses, transport, some industrial sources) is more significant. The maximum annual average air pollution contributions reach the order of hundredths (arsenic) to ten thousandths (benzo (a) pyrene) of the limit value.

5.3. Ecological risks

The estimation of the severity of the risk relates only to air pollution from thermal processes occurring inside the dump. This is an indicative screening estimate; therefore the assessment is simplified, does not contain all the steps and does not meet the requirements for the health risk assessment process. Given the low level of air pollution caused by thermally active dumps, which has been verified by monitoring under the current project, this simplification is acceptable.

The estimation of the average annual immission contribution of benzo [a] pyrene shows that the thermal activity in the bodies of evaluated dumps does not exceed the limit value set at 1 ng.m-3 in inhabited localities. The conservatively estimated air pollution contribution of this substance is 4 to 5 orders lower.

6. Conclusions

There are no ecologically valuable ecosystems in the area of the heaps or in their close vicinity. These are communities of early succession stages, where the main stressor limiting the further development of ecosystems is thermal activity and overheating of the dark surface with low vegetation cover or are common anthropogenically strongly influenced communities with low diversity with prevalence of species with broad ecological amplitude.

Gaseous emissions from thermal oxidation of coal mass within dumps can hypothetically cause environmental risks in the following ways:

– Direct risk in the form of damage to living organisms due to direct contact with polluted air.
– Indirect risk in the form of soil contamination due to air deposition and subsequent transfer to living organisms.

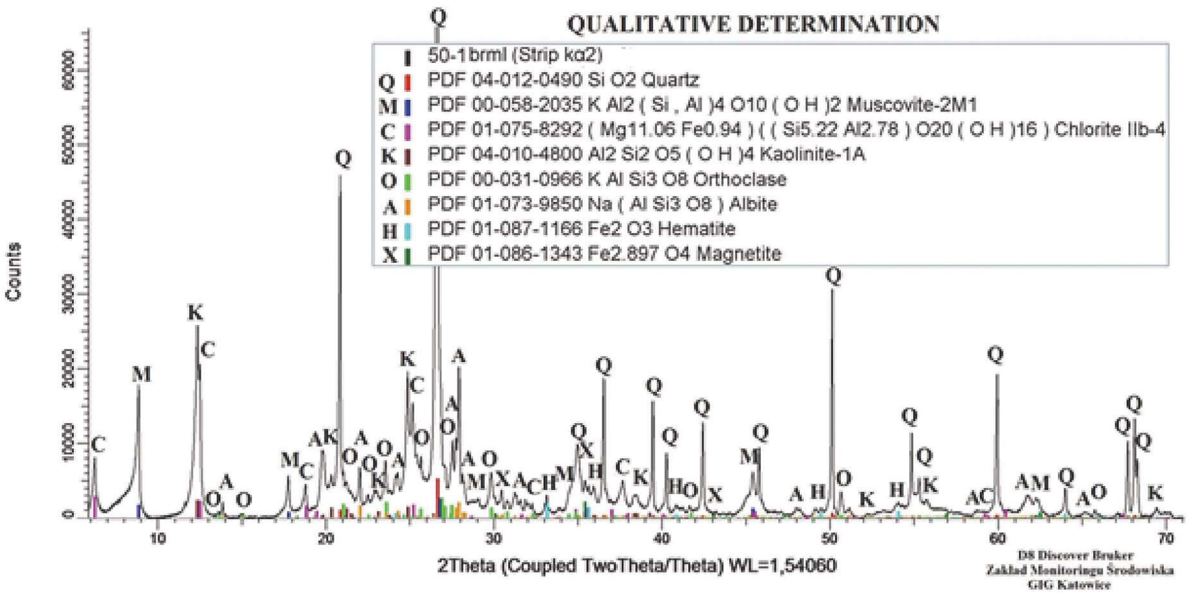


Fig. 4. Diffractogram of dust and its qualitative analysis
Rys. 4. Dyfraktogram pyłu oraz jego analiza ilościowa

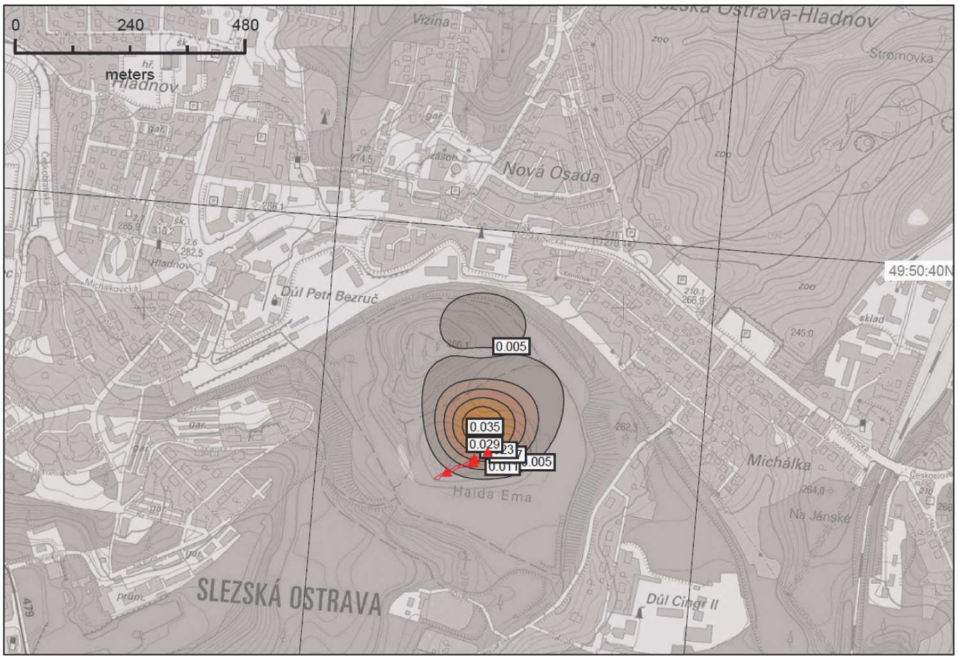


Fig. 5. EMA heap. Total immission contribution to average annual PM10 concentrations (µg/m³)

Rys. 5. Hałda EMA. Całkowity udział imisji w odniesieniu do średniorocznych koncentracji PM10 (µg/m³)

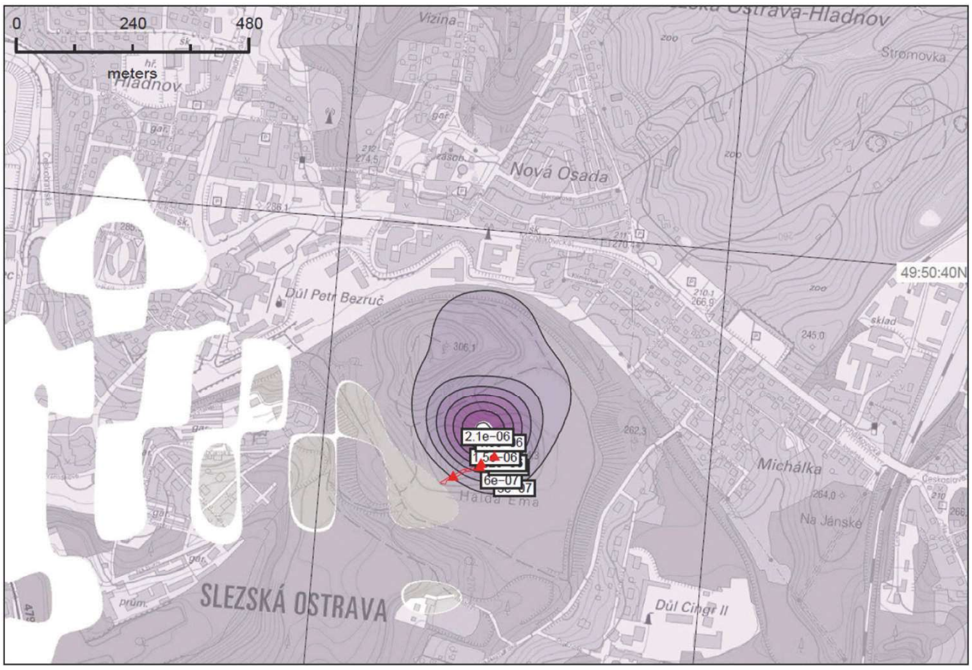


Fig. 6. EMA heap. Total immission contribution to average annual concentrations of B[a]P (ng /m³)

Rys. 6. Hałda EMA. Całkowity udział imisji w odniesieniu do średniorocznych koncentracji B[a]P (ng /m³)

– Indirect risk in the form of soil contamination due to atmospheric deposition, subsequent transfer to surface and groundwater, hence transfer to living organisms.

The impact of these influences is limited practically to the dump body itself, since the immission contributions, and therefore also the deposition and other related effects of pollution, are insignificant hundreds of meters away.

Given that soil screening values include the risk of subsequent transfer to water, following the assessment of the previous point, it can be stated that PAH exhalation from thermal activity in dumps does not present, according to current methodologies, an ecological risk to surface or groundwater.

In summary, emissions from thermal activity cannot detectably increase PAH concentrations in relevant ecosystems off the site of the waste dumps. The associated environmental risks can therefore be excluded.

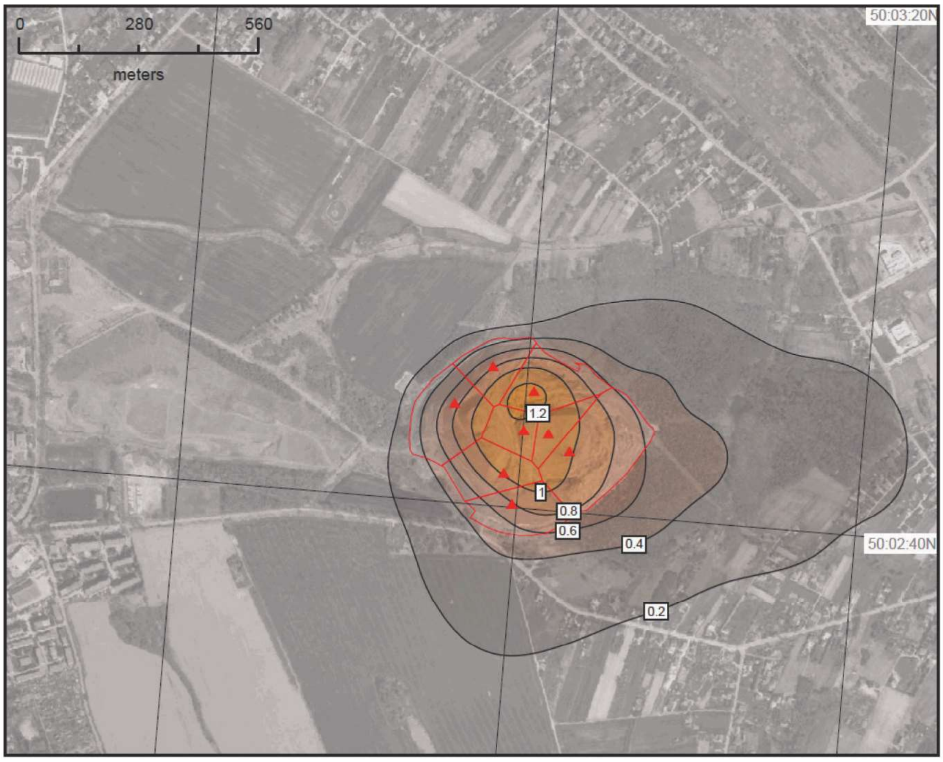


Fig. 7. Pszów location. Total immission contribution to average annual PM10 concentrations (µg/m³)

Rys. 7. Lokalizacja Pszowa. Całkowity udział imisji w odniesieniu do średniorocznych koncentracji PM10 (µg/m³)

Fig. 8. Pszów location. Total immission contribution to average annual concentrations of B[a]P (ng /m³)

Rys. 8. Lokalizacja Pszowa. Całkowity udział imisji w odniesieniu do średniorocznych koncentracji B[a]P (ng /m³)

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