DISTRIBUTION OF POLYCYCLIC AROMATIC HYDROCARBONS (PAHs) IN SOILS AND GROUNDWATERS SURROUNDING A MUNICIPAL WASTE LANDFILL

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Introduction

Municipal solid waste deposited in urban landfills is still a common disposal alternative in most countries. Unsealed urban landfills pose a potential threat to the environment with extensive pollutant sources such as PCBs, PCDDs/Fs, PAHs etc. Transport of pollutants often occurs with the leachate, which are mostly formed of rainwater penetrating the waste. Leachate composition varies depending on the type of waste deposit, landfill age, season, method of operation and the amount of rainfall. Contaminated leachate flow may cause pollution of groundwater and distribution of organic pollutants in soils. [1,2] Old solid waste landfills are especially linked to the risk of soil pollution for the ecosystem. Soils, due to their strong affinity to organic matter are major sinks for organic pollutants. The fate and toxic effect of organic compounds in soils is largely governed by their bioavailability, which is strongly affected by their physical and chemical properties.[3]

One of the groups of compounds present in the leachate generates from landfill are polycyclic aromatic hydrocarbons (PAHs). PAHs and other organic compounds present in the leachate originate from the materials deposited in the landfill, as well as formed during the decomposition of organic matter contained in the waste. Current studies concern mostly the transport of PAHs from unsealed landfills, but there is little research on their further fate in the environment.[1,4] PAHs occur naturally in the environment and are generated by forest fires and volcanic eruption, however the large amount of PAHs released to the environment are from anthropogenic source such as incomplete combustion of organic materials due to industrial activities, house heating, power generation, vehicle emission etc.[5] Due to PAHs toxicity and carcinogenicity United State Environmental Protection Agency defined 16 PAHs compounds belonging to the priority pollutants. The main aim of presented study is to examine content of 13 PAHs from US EPA list (fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, dibenzo(a,h)anthracene, benzo(ghi)perylene, indeno(1,2,3-cd)pyrene) in soils surrounding the urban landfill area, considering landfill as the source of PAHs and assuming that groundwater flow has impact on PAHs distribution in soil horizons.

Materials and methods

The studied municipal area is located within boundaries of Warsaw Plain, a zone of plateau where Vistula floods occurs. The landfill areas are mostly wasteland, further from the landfill there are forest, grasslands and arable fields. In the area of the landfill are distinguished two geomorphological formations: glacial denuded and non-denuded plateau, and river valleys. In the centre of the plateau there is a zone of the fluvioglacial waters flow. The surface runoff from the landfill site is collected in ditch No 2, also the waters are drained periodically from landfill sites by ditch No R (fig.1.). The first level of groundwater table is located within the topsoil consisting of fluvioglacial sands. The drilled depth of groundwater table falls in the range of 0.1 to 1.8 m. The groundwater flow is determined by infiltration of rainfall and by the local drainage. The readings from piezometers allowed the determination of the groundwater flow direction: northwest direction (ditch No. 2) and southeast direction (ditch No. R).[6]

Nineteen sampling sites (soil profiles) were selected (fig.1.). On each site, from depths 0 – 0.2 m, soil samples, represented by a mixture of 12 samples, were collected. Groundwater was collected from 6 sampling points (fig.1.) located in the first aquifer horizon from depths 0.25 m to 0.75 m. Two collection points of surface waters were selected. The sampling points were located on sites of runoff from landfill (ditch No 2 and ditch No R) (fig.1.).

The analyses were carried out according to the ISO 13877 method (1998)[7]. The solvent used to prepare samples was dichloromethane (for HPLC; J.T. Baker). Water samples were extracted using liquid – liquid extraction. Soil samples were extracted for 20 minutes in 100ºC using Dionex Accelerated Solvent Extraction.

Analysis of 13 PAHs was performed using High Performer Liquid Chromatography with fluorescence detector (HPLC-FLD). The chromatographic separation of PAHs was obtained using capillary column Waters PAH C18, S-5µm, 250 x 3.0 mm; mobile phase acetonitrile/water; flow 0.5 ml/min; temperature 30ºC. Quantification of all the investigated PAHs was obtained using signals (peak area) and the calibration curve method. The detection limit of the method was determined at 0,003 ng·g^{-1} for all investigated PAHs analysed together. The recovery efficiencies for 13 PAHs compounds ranged from 70% to 90%. Average relative standard deviation for chromatographic analysis was 10% and average expanded uncertainty of method with 95% confidence interval multiplied by the coverage factor k=2 was about 20 %.

Results and discussion

The highest content of Σ13PAHs with studied landfill soils was less than 1200 ng·g^{-1}. The total content ranges of Σ13PAHs values in studied soils of 0 – 0.2 m layer were 64.53 ng·g^{-1} – 1123.02 ng·g^{-1} (average value 379.74 ng·g^{-1}). The determined value of Σ13PAHs in soils did not exceed the values admissible by Polish law and are comparable to results of studies of the landfills in the world. [5,8,9,10]

The total concentration range of Σ13PAHs values in studying groundwater was 0.045 ng·ml^{-1} – 0.069 ng·ml^{-1} (average value 0.057 ng·ml^{-1}). The average concentration of Σ13PAHs in surface water samples from ditch No 2 and ditch No R were respectively 0.093 ng·ml^{-1} and 0.114 ng·ml^{-1} . The concentration of Σ13PAHs in surface water samples collected from ditches in comparison to concentration in groundwater samples are twice higher, however such low levels of Σ13PAHs in water samples were unexpected. The results of studies the leachate or/and groundwater from landfill areas in the world would suggest higher values.[2,5,9]

Based on the analysis of isoline of PAHs contamination levels versus groundwater flow (fig.1.) confirms the assumption that the distribution of PAHs in soils depends on the watercourse, however, the low levels of concentration of PAHs in groundwater and especially in surface water contradict urban waste landfill being the source of PAHs pollutions. The highest value of PAHs in soil sampling points was located near the car park and landfill facilities, what suggest that vehicles emission and waste management activities like waste transportation or waste unloading were more likely the source of PAHs. Also atmospheric disposition should be included.
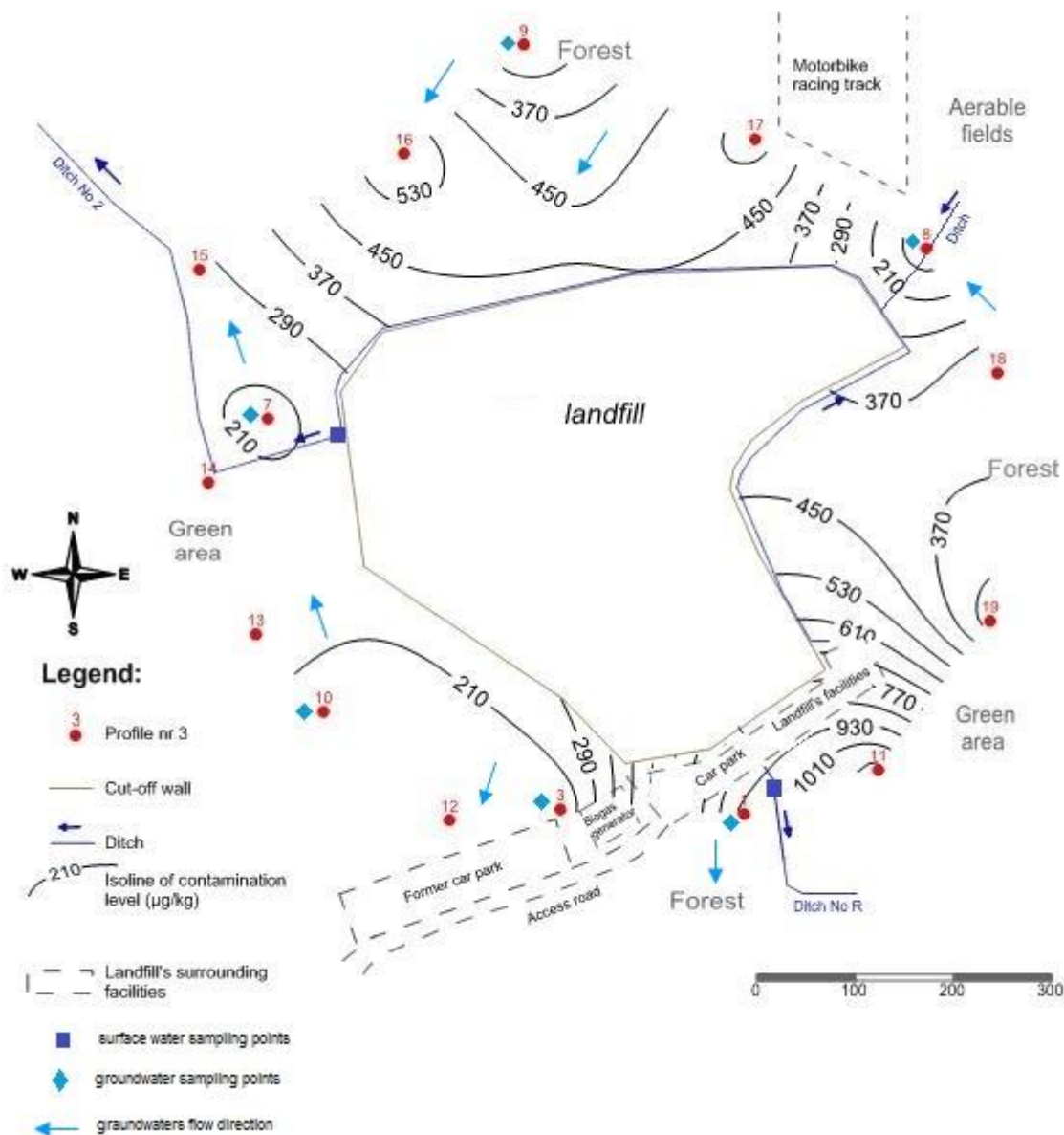
Fig.1. Distribution of PAHs in soils of the waste landfill versus groundwater's flow directions in 0 – 0.2 m layer.

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