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# IMPACT OF COMBUSTION PROCESSES ON SOIL POLLUTION WITH PCBs AND PAHs

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**Abstract:** Polychlorinated biphenyls (PCBs) and polynuclear aromatic hydrocarbons (PAHs) exhibit similar environmental behavior, as both classes of compounds are persistent, hydrophobic, and tend to accumulate in soils, sediments, and biota**.** The present study aims to determine whether, and to what extent, these compounds contribute to soil contamination as a result of combustion processes such as waste incineration, landfill fires, petroleum product combustion, vegetation burning, and domestic burning activities. For this purpose, 33 soil samples were collected and the concentration of PCBs and PAHs were quantified by gas chromatography and ultrahigh performance liquid chromatography, respectively. Regarding PCBs, 52% of the analyzed samples exhibited concentrations within the normal range, while the remaining samples exceeded the upper limit of normal values but remained below the alert threshold. The highest PCB concentration (0.147 mg/kg) was detected in soil collected from the Vidra landfill area. Regarding PAHs, 27.3% of the samples showed concentrations within normal limits, whereas the rest exceeded normal values but remained below the alert threshold of 7.5 mg/kg. The highest PAH level (4.636 mg/kg) was recorded in soil samples collected from the vicinity of the steel plant in Târgoviște. Overall, the study demonstrates that combustion processes represent notable sources of soil contamination by persistent organic pollutants.

**Keywords:** combustion, contamination, PAH, PCBs, soil

## 1. INTRODUCTION

Polychlorinated biphenyls (PCBs), a class of synthetic organic compounds, are widely dispersed in environment, highly persistent, and responsible for various harmful effects on living organisms and the ecosystem, even at low concentrations (Drimal et al., 2016). Of the 209 theoretical isomers obtained by treating biphenyl with chlorine, 150 have been identified in the environment (Mills et al., 2007). PCB isomers have different toxicities. Thus, non-ortho substituted PCBs belong to the group with the highest toxicity, mono-ortho substituted PCBs are moderately toxic, and the remaining are relatively non-toxic (Soniassy et al., 1994). Therefore, the total PCB residue level is not taken into account, instead the concentration of each congener is considered. According to the International Agency for Research on Cancer (IARC), PCBs are classified as Group 1 – carcinogenic to humans.

Their high chemical stability, high electrical resistance, low volatility, and resistance to degradation at elevated temperatures have made them be used extensively from the 1930s to the 1980s. Consequently, PCBs have been used as dielectric fluids in capacitors and transformers, as hydraulic fluids in mining equipment, and as heat transfer fluids or for vacuum pumps. Additionally, they have been utilized in the production of plasticizers and additives, cement, lubricating and cutting oils, and printing inks (Sandu et al., 2025; Hannah et al., 2022).

These characteristics, combined with bioaccumulation along the food chain, have made these compounds ubiquitous in environment. Consequently, their designation as persistent organic pollutants established in 1998 by the Aarhus Protocol and in 2004 by the Stockholm Convention was aimed at restricting their use and reducing their release in the

environment. Despite international regulatory efforts PCBs continue to be widely distributed in the environment due to legacy emissions, inappropriate disposal practices and continued releases from secondary, unintentional sources like waste incineration, metallurgical refining, and cement production (Song et al., 2018). In 2019, Regulation (EU) 2019/1021 stipulates the inclusion of PCBs on the list of substances subject to restrictions together with another class of organic pollutants, named polynuclear aromatic hydrocarbons (PAHs).

Polynuclear aromatic hydrocarbons (PAHs) are organic pollutants composed of two or more condensed rings. The US Environmental Protection Agency (USEPA) declared 16 compounds from the PAHs category as priority pollutants in 1983, due to their presence in the environment at high concentrations, their recalcitrant nature and toxicity (Deziel et al., 2021). PAHs are characterized by low water solubility, low vapor pressure and high boiling and melting points. With increasing molecular weight, water solubility decreases and lipophilicity increases, making them more recalcitrant (Lee & Vu, 2010). They are ubiquitous in environment and, like PCBs, bioconcentrate along the food chain. They have been highlighted in terrestrial, aquatic and atmospheric environments (Adeniji et al., 2019). In soil and sediments, the deposition rate is accelerated due to their lipophilic nature. They are strongly adsorbed by soil particles, which becomes a real reservoir for PAHs (Kuppusamy et al., 2017). Many PAHs have mutagenic, carcinogenic, teratogenic, and immunotoxic properties for living organisms, including microorganisms, mammals and humans (Bolden et al., 2017).

Incineration of industrial and hospital waste, high-temperature processes in industry, uncontrolled burning are all sources of PCBs and PAHs (Berdowski et al., 1997; Ravindra et al., 2008). It is also well known that PAHs result by the incomplete combustion of organic substances and petroleum products (Abdel-Shafy & Mansour, 2016).

## 2. MATERIALS AND METHODS

### 2.1. Soil sampling

A total of 33 topsoil samples (0 - 20 cm) were collected in spring of 2024 from areas potentially affected by combustion processes (Table 1), as follows:

- Combustion by incineration

A waste incinerator in Negoiești (P3) has been selected. PCBs and PAHs emissions can occur during the incineration of municipal and industrial wastes therefore this operation must be carefully controlled, especially with respect to maintaining adequate combustion temperature (over 1100 °C) (Berdowski et al., 1997). During the summer of 2022, a major fire occurred at the incinerator, resulting in the release of a large amount of smoke. Soil samples were collected from the vicinity of the incinerator.

Table 1. Sampling locations.

| Sample code | Sampling location | Latitude (N) | Longitude (E) |
|---|---|---|---|
| P1 | Ploiești 1 | 44°53’01” | 26°00’55” |
| P2 | Ploiești 2 | 44°51’30” | 26°01’17” |
| P3 | Negoiești | 44°52’38” | 25°59’16” |
| P4 | Brazi | 44°53’05” | 25°59’53” |
| P5 | Rudeni | 44°28’51” | 25°58’57” |
| P6 | Botoșani 1 | 47°43’19” | 26°49’48” |
| P7 | Botoșani 2 | 47°43’16” | 26°49’50” |
| P8 | Tulcea | 45°10’40” | 28°46’11” |
| P9 | București | 44°24’26” | 26°09’02” |
| P10 | Vidra | 44°18’39” | 26°07’33” |
| P11 | Jilava | 44°19’40” | 26°04’05” |
| P12 | Chitila 1 | 44°30’15” | 25°58’09” |
| P13 | Chitila 2 | 44°30’15” | 25°58’12” |
| P14 | Chitila 3 | 44°30’19” | 25°58’16” |
| P15 | Florești 1 | 44°27’54” | 25°44’58” |
| P16 | Florești 2 | 44°27’54” | 25°44’59” |
| P17 | Ploiești 3 | 44°55’38” | 26°00’41” |
| P18 | Pitești 1 | 44°52’00” | 24°50’24” |
| P19 | Pitești 2 | 44°50’14” | 24°52’44” |
| P20 | Câmpulung 1 | 45°17’34” | 25°06’49” |
| P21 | Câmpulung 2 | 45°17’43” | 25°06’36” |
| P22 | Câmpulung 3 | 45°17’39” | 25°06’29” |
| P23 | Câmpulung 4 | 45°17’30” | 25°06’31” |
| P24 | Câmpulung 5 | 45°17’10” | 25°06’37” |
| P25 | Târgoviște 1 | 45°54’35” | 25°27’36” |
| P26 | Târgoviște 2 | 45°54’31” | 25°27’56” |
| P27 | Târgoviște 3 | 45°54’13” | 25°26’51” |
| P28 | Târgoviște 4 | 45°53’59” | 25°27’17” |
| P29 | Târgoviște 5 | 45°54’29” | 25°26’55” |
| P30 | Slatina 1 | 44°26’54” | 24°23’11” |
| P31 | Slatina 2 | 44°27’02” | 24°23’29” |
| P32 | Slatina 3 | 44°27’06” | 24°23’11” |
| P33 | Slatina 4 | 44°26’52” | 24°23’07” |

- Combustion of petroleum products

It is expected that soils near the refinery will be contaminated with PAHs because these compounds are found in crude oil and on the other hand, they are formed by the maturation of crude oil through a process called petrogenic. Soil pollution with PAHs can occur following oil spills from underground and above ground storage tanks for gasoline, motor oil and related substances associated with transportation. Soil samples were collected near the oil refinery in Ploiești (P1, P2) and from Brazi (P4).

- Combustion of fuels from thermal power plants

The CET Sud thermal power plant from Bucharest was chosen because is the largest power plant of this type in Romania and even in southeastern Europe. There are studies that have highlighted the unintentional formation of PCBs, especially highly chlorinated ones, in different areas of the thermal power plant where combustion occurs (Ishikawa et al., 2007). Soil samples were collected from an area situated near the power plant (P9).

- Fires that can be intentional and unintentional, like:
  - Accidents, for example the fire at a pigment and dye factory in Jilava (P11). Soil samples were collected two days after the fire accident
  - Vegetation fires

Burning vegetation on agricultural land can lead to the formation of polynuclear aromatic hydrocarbons (Ravindra et al., 2008). To maintain soil organic matter and prevent air pollution, Good Agricultural and Environmental Conditions (GAEC 6) prohibit the burning of stubble and plant residues on arable land, as well as the burning of permanent grassland vegetation. However, media reports have documented instances where this cross-compliance rule has been violated. Consequently, soil samples were collected from agricultural lands in Florești village, Giurgiu County, where burnt stubble was accidentally observed (P15, P16).

- Fires at landfills and waste sites (Figure 1)

Soil samples were collected from Vidra, Rudeni, Botoșani landfills and from a waste storage area from Chitila (P10, P5, P6, P7, P12, P13, P14).

Figure 1. Fire at Rudeni landfill.

Fires at landfills are quite common and can be caused by biogas produced from the fermentation of municipal waste, which can self-ignite. Additionally, certain types of waste, such as batteries, plastic objects, and glass, can contribute to spontaneous combustion. In some cases, landfill fires are deliberately set, often to create space for more waste or to conceal illegal dumping sites.

- Household activities such as waste burning, wood or coal burning for heating can be sources of PAHs (Gupte et al., 2016). Soil samples were collected from old neighborhoods of Ploiești (P17) and Pitești (P18, P19), where homes have stoves or wood-fired heating systems.
- The ferrous and non-ferrous metallurgical industry, as well as steel and cement production, can be sources of PCBs and PAHs through combustion processes (Yang et al., 2018). In this case, the soil was collected from the vicinity of an alumina producer from Tulcea (P8), Slatina (P30, P31, P32, P33), from the surroundings of a steel plant in Târgoviște (P25-P29), and from the area near a cement factory in Câmpulung (P20-P24) (Figure 2).

Figure 2. Area near a steel factory in Târgoviște.

Samples were collected in March when air temperatures averaged 15°C. Each sample was a composite of five subsamples taken from the four corners and the center of a 5 x 5 m² plot. Samples were stored in glass containers, protected from light, and refrigerated until analysis. Soil sampling was conducted at multiple evenly distributed points around a potential pollution source, depending on the field conditions.

### 2.2. Soil physicochemical properties

Soil properties were analysed using standard methods:

- pH: potentiometric method (SR-7184-13)
- Organic Carbon (C, %): wet oxidation method (Walkley-Black, STAS 7184/21-82)
- Mobile Phosphorus (PAL, mg/kg): Egner-Riehm-Domingo method (STAS 7184/19-82)
- Electrical Conductivity (EC, µS/cm): aqueous extract and conductometric method (STAS 7184/7-87)
- Particle Size Distribution: wet/dry sieving and

sedimentation (STAS 7184/7-87)

Clay content ranges between 15% and 34.2%, which corresponds to sandy loam and loam textural classes. The soils investigated in this study display substantial variability in their properties as expected in the case of industrialized urban soils (Table 2).

Table 2. Chemical properties of the analysed soil sample (N=33).

| Parameters | Range |
|---|---|
| pH | 4.98 - 8.08 |
| C (%) | 0.97 - 3.67 |
| N (%) | 0.1 - 0.32 |
| EC (μS/cm) | 22 - 193 |
| P (mg/kg) | 16.34 - 271.2 |

- pH varies from moderately acidic (4.98) to slightly alkaline (8.08);
- The electrical conductivity is closely correlated with the total salt content and has very low values (22 μS/cm – 193 μS/cm).
- The organic carbon varies between 0.97% and 3.67% indicating a low to medium supply.
- The nitrogen content varies between 0.1% (very low) and 0.32% (high).
- The mobile phosphorus content varies between 4.86 mg/kg (extremely low) and 218 mg/kg (very high)
- The potassium content varies between 112 mg/kg (medium) and 438 mg/kg (very high).

### 2.3. PCBs and PAHs determination

PCBs soil analysis is done according with SR EN 17322:2020 and PAHs soil analysis is done according with SR EN 17503:2022, for extraction of PCBs and PAHs from soil, an automated Soxhlet extractor and a mixture of hexane:acetone (1:1) were used. The extract was washed with water for chromatography to remove acetone and then passed through anhydrous sodium sulfate. If necessary to remove the sulphur, copper powder can be used.

The PCBs determination (seven isomers indicated by Order 756/1997: PCB 28, PCB 52, PCB 101, PCB 118, PCB 138, PCB 153, PCB 180) was performed on an Agilent gas chromatograph (GC) equipped with an electron capture detector (ECD), operated at 300°C and a capillary column (30 m x 0.32 mm x 0.25 mm) with a nonpolar stationary phase (DB-5).

The determination of PAHs was performed on a Knauer ultrahigh pressure liquid chromatograph (UHPLC) with UV-VIS detection, at 254 nm.

Order 756/1997 stipulates quantification of the following priority PAHs: anthracene, benzo(a)anthracene, benzo[*b*]fluoranthene, benzo[*k*]fluoranthene, benzo[*a*]pyrene, benzo[*ghi*]perylene, chrysene, fluoranthene, indeno(1,2,3)pyrene, naphthalene, phenanthrene, pyren. The pair consisting of benzo[*ghi*]perylene and indeno(1,2,3)pyrene cannot be determined with this type of detector. The separation of the other compounds was performed with a C18 column (2.1 mm x 100 mm x 1.8 mm) operated at 40°C.

The mobile phase is composed of water and acetonitrile with gradient elution.

To minimize the contamination, all the glassware is rinsed with hexane, acetonitrile and acetone. In order to assure representativeness and reliability of the results obtained, QC/QA procedures include duplicate, blank sample and the analysis of a certified reference material (16-0938, BIPEA). The limit of quantification in soil is 1 μg/kg for PCBs and 10 μg/kg for PAHs (expressed as dry matter).

The interpretation of the results was carried out in accordance with Order 756/1997.

## 3. RESULTS AND DISCUSSION

### 3.1. PCBs content in soil

The total concentration of PCB compounds ranged from below the method's quantification limit (0.001 mg/kg for each isomer) to 0.147 mg/kg. The highest content exceeds approximately 15 times the upper limit of normal concentrations (<0.01 mg/kg) but remains below the alert threshold (0.25 mg/kg). The highest concentration was observed at sampling point P 10, collected from the Vidra landfill (Figure 3). Increased PCB concentrations were also observed at several points: P5, collected from the Rudeni landfill (0.099 mg/kg); P7, from the Botoșani landfill (0.044 mg/kg); P9, near the CET Sud thermal power plant (0.056 mg/kg); P25, in the vicinity of the Târgoviște steel plant (0.057 mg/kg); and P30 and P33, near the aluminium company in Slatina (0.059 mg/kg and 0.067 mg/kg, respectively). In contrast, the lowest PCB concentrations were detected in soils from the waste storage in Chitila, from Negoiești incinerator, and Florești, where evidence of burnt stubble was observed. Sandu et al. (2025) demonstrated that PCBs accumulation is significant in industrial areas such as Militari, Pipera, and Băneasa. Also, Salihoglu et al. (2011) concluded that intense industrial activity, including iron and steel plants, a refinery, and a petrochemical complex, is the main source of high levels of PCB contamination in soil.

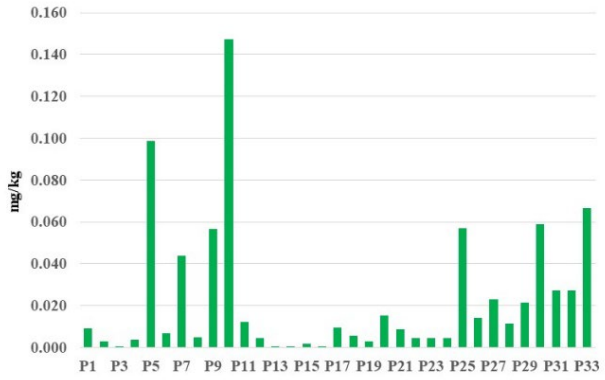


Figure 3. PCB total content in analyzed soils

Regarding the contribution of the isomers to the total PCB content, the following were found:

- PCB 28, the isomer with 3 chlorine atoms in molecule, the most volatile and the most easily biodegradable, was detected at an average concentration of 0.0015 mg/kg, a value 1.5 times higher than the upper threshold of normal values (<0.0001 mg/kg), but below the alert threshold (0.002 mg/kg). The highest concentration value of 0.012 mg/kg was obtained at point P 11 collected from the soil located in the immediate vicinity of the pigment and dye factory in Jilava where a fire had occurred. This concentration exceeds the intervention threshold of 0.01 mg/kg. It is not possible to ascertain whether PCB 28 resulted from the fire or was pre-existing in the soil. No studies in the specialized literature have directly linked the occurrence of PCB 28 to fires. However, Hu & Hornbuckle (2010) reported the presence of lower chlorinated PCB congeners in pigments.
  PCB 28 contributes about 8.56% to the total PCB concentration (Figure 4).

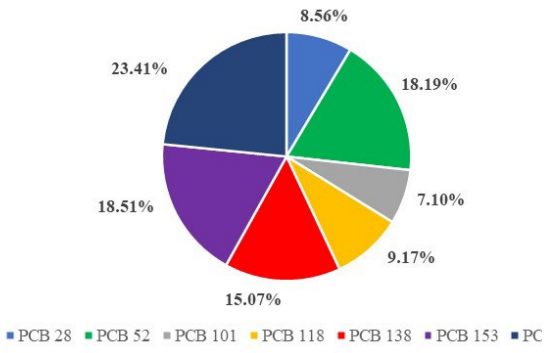


Figure 4. The contribution of the seven isomers to the total content of PCBs

- PCB 52 is the isomer with 4 chlorine atoms in the molecule. It contributes 18,19% to the total concentration of PCB (Figure 4). In this case, 33.3% of the analyzed soil samples have normal contents (<0.0001 mg/kg), 43.3% have contents higher than the upper threshold of normal values, but lower than the alert threshold (0.002 mg/kg), 13.4% have concentrations that reach and even exceed the alert threshold, and 10% exceed the intervention threshold (0.01 mg/kg). The highest values were obtained at P5 and P 6 collected from Rudeni and Botoșani landfills and also in P 17 - the residential area of Ploiești. Pănescu et al. (2024) reported that PCB 52, PCB 138 and PCB 28 were the most prelevant compounds in a low-income residential area populated by Roma communities from Transylvania region.
- The pentachlorinated isomers, PCB 101 and PCB 118 have a smaller contribution to the total PCB content (7.10%, respectively 9.17%) (Figure 4). Their concentrations are either normal or exceed the upper limit of normal values (<0.0004 mg/kg), but are much lower than the alert threshold (0.01mg/kg). The highest values were recorded, in both cases at Vidra landfill.
- PCB 138 and PCB 153, the hexachlorinated congeners exhibit the highest contributions to the total PCB concentration (33.6%). This can happen due to a combination of their historical prevalence in commercial PCB mixtures, their physicochemical properties, and their exceptional environmental persistence. Both congeners are major components of widely used Aroclor formulations (particularly Aroclor 1254 and Aroclor 1260) (Faroon & Keith, 2003), which were extensively applied in electrical equipment, hydraulic fluids, and various industrial materials. From a physicochemical perspective, these congeners exhibit very low water solubility, low vapor pressure, and high octanol–water partition coefficients (log $K_{ow}$ ~6.5–7), characteristics that promote strong adsorption to organic matter in soils and sediments and limit their mobility and volatility (Li et al., 2003). Their specific chlorine-substitution patterns confer substantial resistance to microbial degradation and metabolic transformation, allowing them to persist for decades under both aerobic and anaerobic conditions (Urbarniak, 2007). The highest values were obtained in soils collected from the Rudeni and Botoșani landfills and the CET Sud thermal power plant.
- PCB 180, the heptachlorinated congener contributes 23.41% to the total content of PCBs. In this case, 12% of the analyzed samples have concentrations exceeding the

alert threshold, the highest values being recorded at the Vidra, Rudeni, Botoșani landfills and again at CET Sud. Similar results were obtained by Gedik & Imamoglu (2011).

### 3.2. PAHs content in soil

The total content of polynuclear aromatic hydrocarbons in the studied soils ranges between 0.052 mg/kg and 4.636 mg/kg with an average of 0.488 mg/kg (Figure 5). All soil samples are contaminated with these compounds, 27.3% having normal concentrations (<0.1 mg/kg), whereas the remaining samples have contents that exceed normal values, but are below the alert threshold of 7.5 mg/kg. The highest values were obtained in soil samples collected from area located near the steel plant in Târgoviște (P 25, P26), and in the vicinity of the plant in Slatina (P 33). Similar results were reported by Wang et al. (2010) who found PAH concentrations ranging between 0.031 mg/kg and 1.475 mg/kg in soil collected from an industrial city.

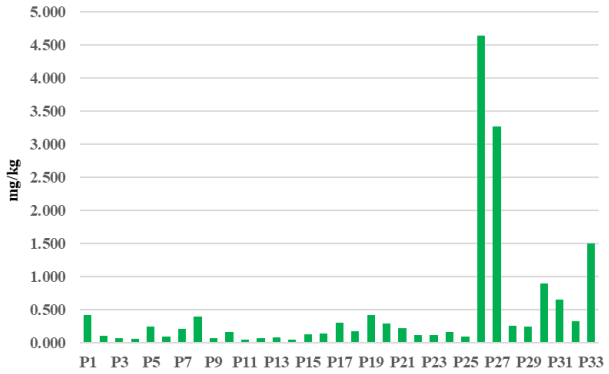


Figure 5. PAHs concentration in analyzed soil samples.

In contrast, Ene et al. (2012) investigated PAH levels in the vicinity of the Galați iron and steel plant and reported concentrations ranging from 0.003 mg/kg to 38.524 mg/kg, indicating a considerably higher degree of pollution.

Regarding the contribution of each PAH compound to the total concentration, the following can be noted:

- Naphthalene, consisting of two aromatic rings, contaminates only 30% of the soil samples analyzed. The highest value of naphthalene concentration, 0.091 mg/kg, recorded at the Rudeni landfill (P5). This value exceeds the upper threshold of normal values (<0.02 mg/kg), but is about 20 times smaller than alert threshold (2 mg/kg). High concentration values were also recorded in the old residential area of Ploiești (0.082 mg/kg) (P17), in the Florești village (P15, P16), in the burned stubble area (0.028 mg/kg and 0.022 mg/kg, respectively), at the thermal power plant P9 (0.012 mg/kg). At these points, the upper threshold of normal values was again exceeded but the alert threshold was not reached. Both at the Rudeni landfill and in the old residential area of Ploiești, higher contents were observed. Naphthalene is a low molecular weight aromatic hydrocarbon (LMW-PAH). This class of PAHs is generated predominantly through combustion processes occurring at low to moderate temperatures. In the present study, naphthalene is attributed to emissions from household wood-burning stoves, stubble burning, landfill fires, and combustion activities associated with power plants. Similar results were obtained by Jia & Batterman (2010).
- Anthracene was detected in 43.3% of the studied soil samples, its concentration ranging from below the method's quantification limit (0.01 mg/kg) to 0.035 mg/kg, with an average of 0.024 mg/kg. The highest concentration value (0.035 mg/kg) was recorded in the soil collected from the vicinity of the Tulcea alumina plant. A similar concentration (0.014 mg/kg) of anthracene was obtained by Borgulat & Staszewski (2018) near an aluminum smelter.
- Fluoranthene is a four ring LMW-PAH. It is a structural isomer of pyrene. It contaminates all soil samples analyzed in concentrations ranging from 0.040 mg/kg to 1.860 mg/kg, with an average of 0.628 mg/kg. The highest concentrations were observed in soil samples collected near the steel plant in Târgoviște (P25, P26) and in the vicinity of the industrial site in Slatina (P33). Xu et al. (2021) reported an average fluoranthene concentration of 1.059 mg/kg in soil collected from an industrial city, a finding comparable to that observed in the present study.
- Pyrene, benzo(a)anthracene and chrysene each contain four rings in molecule. Pyrene contaminates 86.7% of the analyzed samples and has concentrations ranging from undetectable to 0.055 mg/kg, with an average of 0.017 mg/kg. The highest load level is recorded in the soils collected from an old residential area of Ploiești (P17). Benzo(a)anthracene was detected in 70% of the analyzed samples, with a maximum concentration of 0.045 mg/kg measured at the same P17. Chrysene was present in 56.6% of

the samples, reaching a maximum concentration of 0.091 mg/kg in soil collected from the area adjacent to the Negoiesti incinerator. Benzo(b)fluoranthene, benzo(k)fluoranthene and benzo(a)pyrene each contain 5 rings in the molecule and contaminate 70%, 43.3% and 46.6% of the analyzed samples, respectively. The highest concentration values are: 1.415 mg/kg benzo(b)fluoranthene, 0.433 mg/kg in for benzo(k)fluoranthene and 0.032 mg/kg benzo(a)pyrene. These values of concentrations were recorded in the soil sample collected from the area situated near the steel plant in Târgoviște (P 25, P26), and in the vicinity of the plant in Slatina (P 33). Xu et al., (2021) also reported the presence of these PAHs in an industrial area.

It should be highlighted that the concentrations of all studied compounds remain below the alert threshold of 2 mg/kg.

The contamination of soils collected from landfill, industrial, or residential areas with PAHs may result from a combination of contributing factors. Because different sources produce distinctive patterns of PAH compounds, scientists use diagnostic ratios to distinguish them. Diagnostic ratios are used to distinguish between pyrogenic (fire-related) and petrogenic (oil or fossil fuel-related) sources of polycyclic aromatic hydrocarbons. In practice, PAHs contamination frequently results from mixed sources—such as simultaneous inputs from vehicular emissions and industrial activities—further complicating source attribution. Nevertheless, despite these limitations, diagnostic ratios remain a commonly applied and valuable tool in a wide range of environmental settings for the preliminary apportionment and assessment of PAH sources (Yunker et al., 2002; Tobiszewski & Namieśnik, 2012). The following diagnostic ratios were used to indicate possible sources (Davis et al., 2019):

- ∑LMW/∑HMW PAHs
- Anthracene/ (Anthracene + Phenanthrene)
- Fluoranthene/ (Fluoranthene + Pyrene)
- Benzo[a]anthracene/(Benzo[a]anthracene + Chrysene)

Values of ratio ∑LMW/∑HMW PAHs smaller than 1 suggest pyrogenic sources, while a value greater than 1 suggests petrogenic sources (Zhang et al., 2008). In this case, the ratio ranged from 0.11 to 1.12, suggesting the pyrogenic sources may be most impactful in soil collected (Figure 6). Practically, only one sampling point, collected from Brazi, shows a ratio exceeding the value of 1, indicating a petrogenic source.

The Anthracene/ (Anthracene + Phenanthrene) ratio distinguishes between petrogenic and combustion sources, as values < 0.1 indicate petrogenic and those > 0.1 indicate combustion (Yunker et al., 2002). Values obtained for this ratio ranged between 0.13 and 0.74, so the source is combustion (Figure 7).

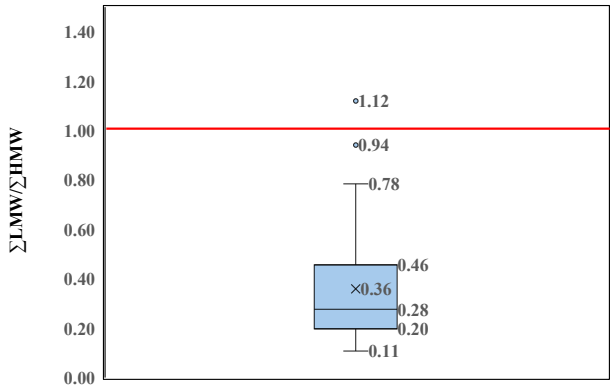


Figure 6. PAH diagnostic ratio plot of ∑LMW/∑HMW

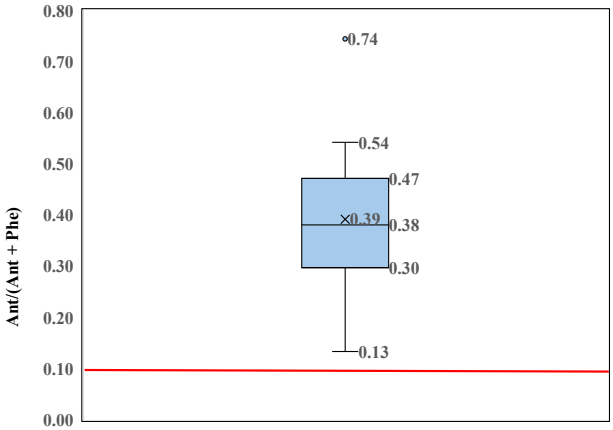


Figure 7. PAH diagnostic ratio plot of Ant/ (Ant + Phe)

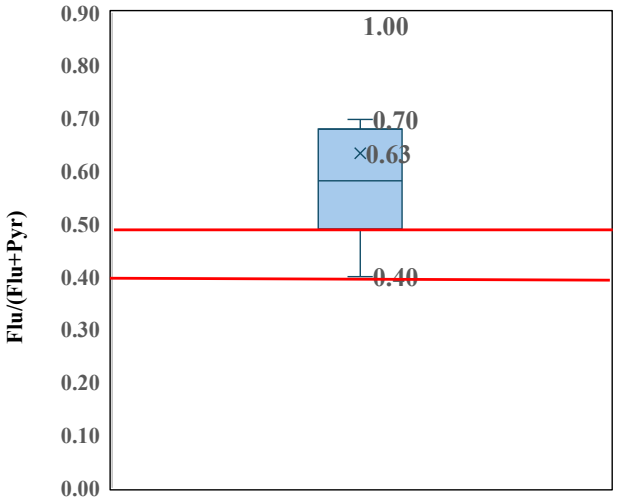


Figure 8. PAH diagnostic ratio plot of Flu/(Flu+Pyr)

The Fluoranthene/(Fluoranthene + Pyrene) ratio provides valuable insight into distinguishing

between petroleum sources, petroleum combustion, and other combustion processes.

Ratio values < 0.4 indicate petrogenic sourcing, values between 0.4 and 0.5 are indicative of petroleum combustion, while values > 0.5 suggest wood, grass, and/or coal combustion (Yunker et al., 2002).

As can be seen in Figure 8, there is only one diagnostic ratio value indicating oil combustion (0.4), which corresponds to point P4 collected from Brazi, while the others are greater than 0.5, indicating a combustion process.

The Benzo[a]anthracene/(Benzo[a]anthracene + Chrysene) ratio distinguishes between petrogenic and combustion (pyrogenic) sources, with a range indicating mixed sourcing. Values below 0.2 suggest petrogenic sources, values between 0.2 and 0.35 indicate mixed sources, while values above 0.35 point to combustion sources (Yunker et al., 2002). According to Figure 9, this ratio ranged between 0.3 and 0.97. Only in point P4 the diagnostic report BaA/ (BaA + Chr) indicate a combination of petrogenic and pyrogenic sources, in the remaining points the source of contamination with PAHs is combustion.

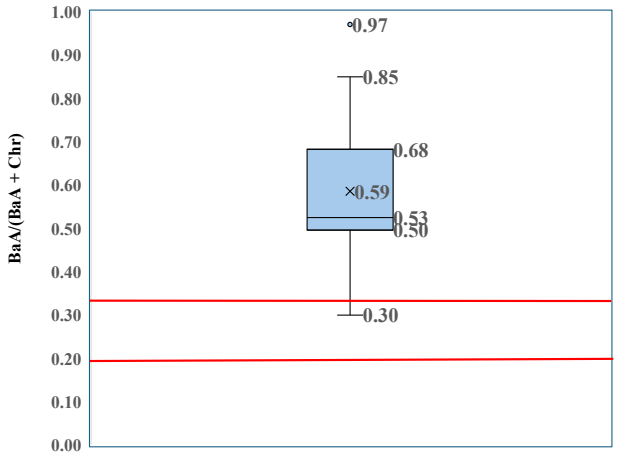


Figure 9. PAH diagnostic ratio plot of BaA/ (BaA + Chr)

## 4. CONCLUSIONS

Total PCB concentrations varied from values below the method quantification limit (0.001 mg/kg per isomer) to a maximum of 0.147 mg/kg. The highest concentration, measured at sampling point P10 from the Vidra landfill, exceeds the upper limit of normal value (<0.01 mg/kg) by approximately an order of magnitude, yet remains below the regulatory alert threshold of 0.25 mg/kg.

Soil contamination with PCB compounds is also present at the sampling points collected from the Rudeni and Botoșani landfills, as well as in the vicinity of the CET Sud thermal power plant, the steel factory in Târgoviște, and the aluminum producer in Slatina.

The total concentrations of PAHs in the investigated soils ranged from 0.052 mg/kg to 4.636 mg/kg. All samples exhibited PAH contamination, with 27.3% remaining within normal levels (<0.1 mg/kg), while the remainder exceeded these values stayed below the alert threshold of 7.5 mg/kg. Near the steel plant in Târgoviște and in close proximity to the aluminium producer in Slatina, soils had the highest concentrations recorded.

Based on the diagnostic ratio analysis, the soil contamination is predominantly associated with combustion-related (pyrogenic) inputs. However, at point P4 (Brazi), the results suggest a mixed origin of contamination, involving both petrogenic sources (related to petroleum products) and pyrogenic sources (arising from combustion).

In conclusion, the study shows that combustion processes are significant sources of soil contamination by these two classes of persistent organic pollutants.


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