ASSESSMENT OF PETROLEUM-RELATED HYDROCARBONS IN AGRICULTURAL SOILS OF THE PATOS–MARINZA AREA

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Abstract

This study shown the occurrence and distribution of petroleum-related hydrocarbons in agricultural soils from the Patos–Marinza area, the most important oil-producing region in Albania. Samples were collected in April 2026 from several locations of Belin, Marinza, Kuman and Zharrëz (part of Patos-Marinza area). Polycyclic aromatic hydrocarbons (PAHs), BTEX compounds and n-alkanes were analysed using gas chromatography with flame ionization detection (GC/FID). The aim of the study was to evaluate the level of hydrocarbon contamination in soil samples (agricultural soils) and to identify the most polluted sites of this impacted area from the extracting of oil processes. In agricultural soils, total PAHs ranged from 0.645 to 2.555 mg/kg, total BTEX from 0.679 to 3.370 mg/kg, and total n-alkanes from 0.752 to 2.536 mg/kg. The most contaminated soil samples were in two stations at Zharrëz, indicating strong accumulation of petroleum-derived hydrocarbons in agricultural land. The presence of BTEX, PAHs and n-alkanes in agricultural soil suggests mixed hydrocarbon contamination, likely associated with oil extraction, transport, runoff, atmospheric deposition and weathered petroleum residues. Soils can accumulate hydrocarbons (and other pollutants) making this sample type strongly influenced by pollution, especially when the source of pollution is in short distances, intense and for a prolonged time. The findings highlight the necessity for continued monitoring, seasonal sampling, and further ecological and agricultural risk evaluation in this area.

Key words: *Patos-Marinza area, Soil samples, PAH, BTEX, n-Alkanes, GC/FID.*

Përmbledhje

Ky studim tregon praninë dhe shpërndarjen e hidrokarbureve të lidhura me ndotjen nga nafta në tokat bujqësore nga zona Patos-Marinza, rajoni më i rëndësishëm prodhues i naftës në Shqipëri. Mostrat u mblodhën në Prill 2026 nga disa stacione të zonës të Belinit, Marinzës, Kumanit dhe Zharrzës (pjesë e zonës Patos-Marinza). Hidrokarburet aromatike policiklike (PAH), përbërjet BTEX dhe n-alkanet u analizuan duke përdorur kromatografinë e gaztë me detektor të jonizimit në flakë (GC/FID). Qëllimi i studimit ishte të vlerësojë nivelin e ndotjes së hidrokarbureve në mostrat e tokës (tokat bujqësore) dhe të identifikohen zonat më të ndotura të këtij rajoni të prekur nga proceset e nxjerrjes së naftës.

Në tokat bujqësore, PAH-të totale varionin nga 0.645 në 2.555 mg/kg, BTEX totale nga 0.679 në 3.370 mg/kg dhe n-alkanet totale nga 0.752 në 2.536 mg/kg. Mostrat më të ndotura të tokës ishin në dy stacione në Zharrëz, duke treguar një akumulim të fortë të hidrokarbureve të nxjerra nga nafta në tokat bujqësore. Prania e BTEX, PAH dhe n-alkaneve në toka bujqësore sugjeron ndotje të hidrokarbureve, që mund të jetë pasojë direkte e nxjerrjes të naftës, transporti, prurjet nga ujrat e vaditjes, depozitimet atmosferike dhe derdhjet e mbetjeve të naftës. Tokat mund të grumbullojnë/adsorbojnë hidrokarbure (dhe ndotës të tjerë), duke e bërë këtë lloj mostre të ndikuar fuqishëm nga ndotja, veçanërisht kur burimi i ndotjes është në distanca të shkurtra, shumë intensiv dhe për një kohë të zgjatur. Rezultatet nxjerrin në pah nevojën për monitorim të vazhdueshëm, marrje mostrash sezonale dhe vlerësim të mëtejshëm të rrezikut ekologjik dhe bujqësor në këtë zonë.

Fjalë kyçe: *Zona Patos-Marinza, Mostrat e tokës, PAH, BTEX, n-Alkane, GC/FID.*

Introduction

The Patos–Marinza area, located in the Fier region of south-western Albania, represents one of the most important petroleum-producing zones in the country and one of the largest on-shore oil-fields in Europe. The development of this oil-field has played a central role in the Albanian petroleum sector for decades, contributing to national energy production, employment and industrial activity. However, based on the raports of National Agency of Natural Resources. (2019) the long history of crude oil extraction (for around 100 years), and occasional accidental releases has also created significant environmental pressure on surrounding environment and especially in soils and agricultural land. Previous assessments have described the Patos–Marinza oil-field as a large industrial area with high contamination potential for soil, groundwater, surface water and air, due to the density of wells and the long-term presence of oil extraction infrastructure (Borshi *et al*, 2016; Hoxha *et al*, 2018; Halo *et al*, 2023).

The environmental sensitivity of the Patos–Marinza area is increased by the co-existence of petroleum industry and agricultural activity in the same area. Agricultural soils can be polluted by hydrocarbons through direct deposition of oil residues, contaminated runoff, irrigation with polluted waters, atmospheric depositions and combustion particles, as well as flooding, leakage from oil infrastructure or improper disposal/discharges of petroleum wastes. Industrial activity at Patos–Marinëz area can affects larger areas including agricultural lands of this area and wider (WFD, 2021; Hoxha *et al*, 2018). Once hydrocarbons enter soils, they can be adsorbed by organic matter and fine particles, undergo partial bio-degradation or volatilization, and potentially affect soil fertility, microbial communities and crop quality. Recent reviews emphasize that petroleum hydrocarbon contamination remains a major environmental challenge because these pollutants can persist in soil, migrate to groundwater and require site-specific remediation strategies (Wu *et al*, 2022; Mekonnen *et al*, 2024; Li *et al*, 2024; Koshlaf & Ball, 2017; Jiang *et al*, 2025; Arias-Navarro *et al*, 2025).

Among the most relevant petroleum-related contaminants are polycyclic aromatic hydrocarbons (PAHs), benzene, toluene, ethylbenzene and xylenes (BTEX), and aliphatic hydrocarbons. Agricultural soils near oil-fields represent an important monitoring matrix. Soil can act both as a sink and a secondary source of hydrocarbons. Hydrophobic compounds such as high molecular weight PAHs and heavier n-alkanes may remain in the upper soil layers for long periods, especially when organic matter content is high. These compounds may affect soil microbial activity, reduce fertility and create possible pathways for human exposure through dust, dermal contact or food-chain transfer. Reviews on petroleum-contaminated soils indicate that improper disposal of oily wastes and delayed remediation can cause long-term soil and water contamination, requiring integrated approaches such as monitoring, risk assessment and remediation (Ambaye *et al*, 2022; Asejeje *et al*, 2024; Jiang *et al*, 2025; Li *et al*, 2024; Daâssi & Almaghribi, 2025, Brzeszcz *et al*, 2023; Akinnusotu *et al*, 2023; Almuhtaseb *et al*, 2024; Berríos-Rolón *et al*, 2025).

Gas chromatography is the most widely used analytical techniques for petroleum hydrocarbon assessment. GC/FID is particularly useful for the quantification of hydrocarbons because the flame ionization detector provides a stable and sensitive response for organic compounds containing carbon–hydrogen bonds. It is commonly applied for BTEX, PAHs and total petroleum hydrocarbon fractions after appropriate extraction and clean-up procedures. Although GC/MS provides stronger confirmatory identification, GC/FID remains a practical and reliable method for routine screening and quantification when calibration, quality control and chromatographic separation are properly applied (Almuhtaseb *et al*, 2024; Nuro *et al*, 2014; Asejeje *et al*, 2024).

The present study focuses on the occurrence of PAHs, BTEX and n-alkanes in agricultural soils from the Patos–Marinza area, sampled in April 2026. The study aims to evaluate the spatial pattern of hydrocarbon contamination, identify the most impacted sites and to show possible connections between petroleum extraction, processing (anthropogenic activities) and agricultural soil quality. This study can be important for understanding environmental pressure and for supporting future monitoring, risk assessment and remediation strategies in one of Albania’s most important oil-producing regions.

Material and methods

2.1. Sampling of agricultural soils at Patos-Marinza area

For this study, soil samples were analyzed from different stations of Patos - Marinza area (Figure 1). Samples were collected in April 2026 from several locations of Belin (3 stations), Marinza (3 stations), Kuman (3 stations) and Zharrëz (2 stations). Soil samples were selected in agricultural areas that are in use from the farmers. Samples were taken up to 30 cm depth. Primarily, samples were air dried and after being ground in a porcelain mortar, they were sieved to obtain the 63 micron fraction for further analysis.

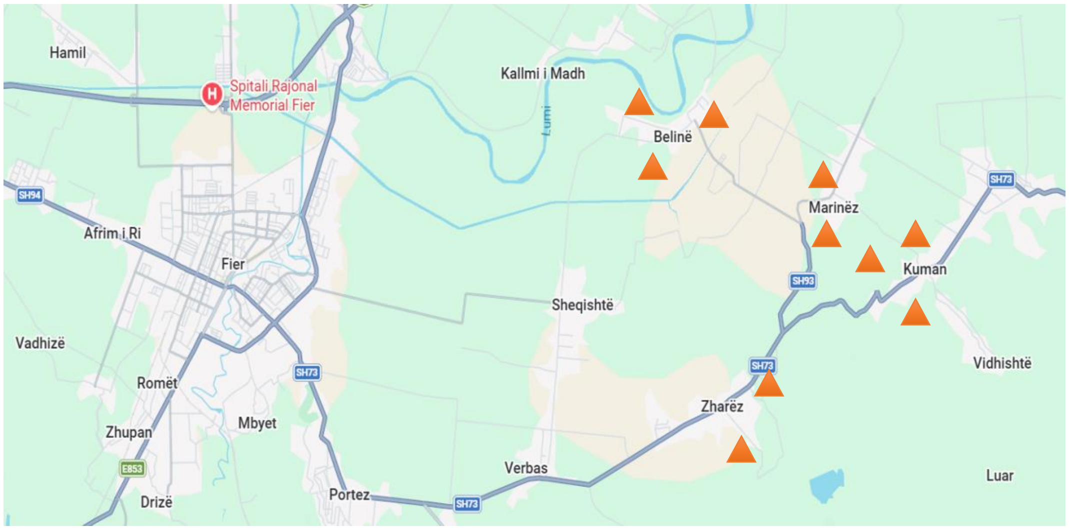

Figure 1. Sampling station in Patos-Marinza area, April 2026

2.2. Soil samples treatment for PAH and n-alkane analyzes

For the simultaneous determination of PAH and n-alkanes, around 20 g of soil sample (from 63 micron fraction) were taken in a 100 ml Erlenmeyer where 50 ml of n-hexane/dichlormethane (4/1) was added as extraction solvent. Their extraction was performed by using ultrasonic bath for 60 minutes at 30^{o}C. The clean-up of organic phase was performed in an aluminium column (SPE). The organic solvents was evaporated using Kuderna-Danish up to 2 ml. The extract was injected in the gas chromatograph equipped with FID detector (Akinnusotu *et al*, 2023; Daâssi & Almaghribi, 2025, Nuro *et al*, 2014).

2.3. GC/FID determination of PAH and n-alkanes in soil samples

Gas chromatography analyzes of 13 most toxic PAHs (EPA 525) and C10-C26 n-alkanes were realized simultaneously in a Varian 450 GC apparatus equipped with a flame ionization detector and a PTV injector. Capillary column VF-1 ms (30m x 0.33mm x 0.25µm) was used for the separation of aliphatic and aromatic hydrocarbons. The temperature for PTV injector (splitless mode) and FID were respectively 260^{o}C and 280°C. Nitrogen was used as carrier gas (1 ml/min) and make-up gas (24 ml/min). Hydrogen and air were the flame detector gases at 30 ml/min and 300 ml/min, respectively. The EPA 525 standard mixture was used for qualitative and quantitative PAH analysis. Acenaphthylene, Fluorene, Phenanthrene, Anthracene, Pyrene, Benzo [a] anthracene, Chrysene, Perylene, Fluoranthene, Benzo [b] fluoranthene, Indeo [1,2,3-cd] pyrene, Dibenzo [a, b] anthracene and Benzo [g, h, i] perylene and the mixture of C10-C26 n-alkanes were determined in soil samples. Hydrocarbon quantification was based on the ESTD method (Halo *et al*, 2025; Nuro *et al*, 2014; Borshi *et al*, 2018).

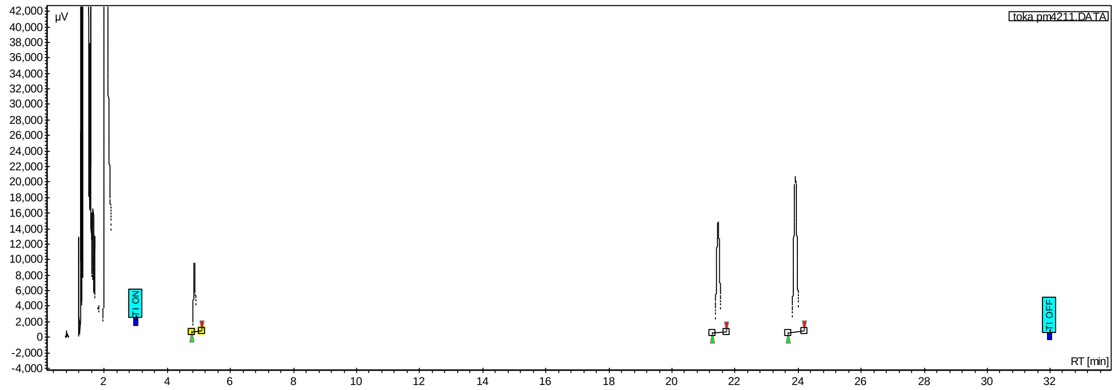

Figure 2. GC/FID chromatograms for PAH and n-alkanes (sample Marinza 2)

2.4. HS-SPME technique for determination of BTEX in soil samples

Determination of BTEX in soil samples was realized using solid phase micro-extraction in static head space mode (HS/SPME) followed by GC/FID technique. 2.5 g of soil sample was insert in a 10 ml head space vial. 100 um PDMS fiber was used to extract BTEX from the samples. Adsorption process was realized in 50°C (using a water bath) for 30 minutes. Desorption process (20 seconds in 260°C) was realized in a PTV injector (HS mode was selected) of a Varian 450 GC instrument. VF-1 ms capillary column (30 m x 0.33 mm x 0.25 μm) was used for separation of Benzene, Toluene, Ethyl benzene and Xylene isomers. The injector and FID temperature was held respectively at 260°C and 280°C. Nitrogen was used as carrier gas (1 ml/min) and make-up gas (24 ml/min). BTEX Mixture was used for their qualitative and quantitative analyze based on external standard method (Nuro *et al*, 2014; Bak *et al*, 2025).

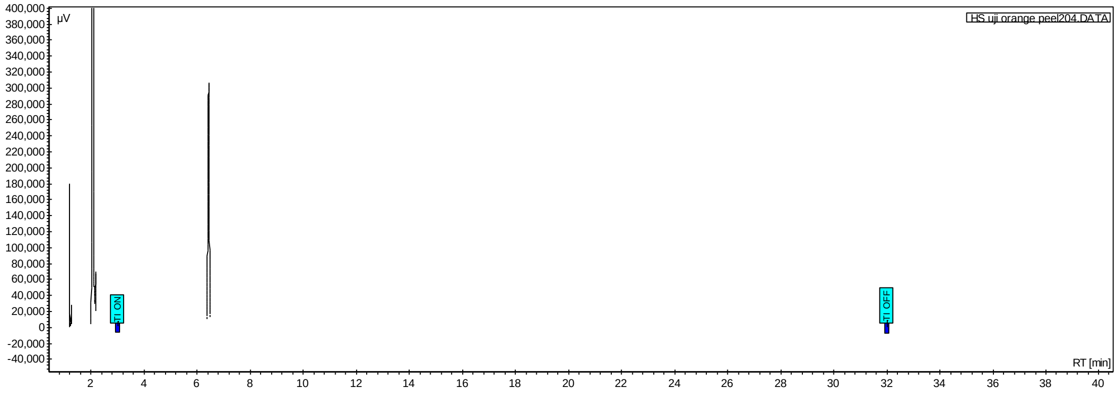

Figure 3. HS-SPME chromatogram for BTEX analyze (Marinza 2 sample)

2.5. Method evaluation

Method performance was evaluated using calibration standards, procedural blanks, replicate analyses and recovery experiments. Recovery tests were performed by spiking uncontaminated soil samples with known concentrations of PAH, n-alkane and BTEX standards prior to extraction. The recovery percentages were calculated by comparing the measured concentrations with the spiked concentrations. Each sample was analyzed at least in triplicate, and the results are reported as mean values. Method detection limits (LOD) and limits of quantification (LOQ) were estimated based on signal-to-noise ratios of 3 and 10, respectively. The full validation methods was realized before measurements according to international analytical quality requirements of ISO 13859:2014 standard. Some data that were used to evaluate the method are given in the following table:

Table 1. The data for the method evaluation

Compound	R2	LOD (ppm)	LOQ (ppm)	Recovery %
PAH				
Acenaftilene	0.9962	0.05	0.15	72.8
Fluorene	0.9954	0.05	0.15	85.3
Phenantrene	0.9857	0.05	0.16	84.2
Anthracene	0.9921	0.05	0.15	78.3
Pyrene	0.9930	0.05	0.15	84.2
Benzo[a]anthracene	0.9755	0.05	0.16	95.2
Chrysene	0.9984	0.05	0.15	98.2
Perilene	0.9934	0.05	0.15	102.3
Benzo[b]fluoranthrene	0.9918	0.05	0.15	98.2
Benzo[k]fluoranthrene	0.9882	0.05	0.16	74.2
Indeo[123cd]Pyrene	0.9826	0.05	0.16	105.2
Dibenzo[ab]Anthracene	0.9932	0.05	0.15	84.2
Benzo[ghi]Perilene	0.9914	0.05	0.15	91.5
n-Alkanes				
C10	0.9957	0.05	0.15	98.2
C12	0.9825	0.05	0.15	95.3
C14	0.9932	0.05	0.15	91.2
C16	0.9991	0.05	0.15	89.3
C18	0.9855	0.05	0.15	102.3
C20	0.9914	0.05	0.15	85.3
C20x	0.9887	0.05	0.16	88.1
C22	0.9964	0.05	0.15	96.4
C24	0.9917	0.05	0.15	80.2
C26	0.9928	0.05	0.15	84.9
BTEX				
Benzene	0.9965	0.05	0.16	88.3
Toluene	0.9992	0.05	0.15	85.2
m-Xylene	0.9857	0.05	0.16	79.3

p-Xylene	0.9836	0.05	0.16	75.2
o-Xylene	0.9925	0.05	0.15	77.1
Ethylbenzene	0.9981	0.05	0.15	81.5

Results and discussion

In this study, agricultural soil samples were taken from the Patos-Marinza area in April 2026. In order to assess the impact of the oil extraction industry on agricultural soils, PAHs, BTEX and n-alkanes were analyzed. These hydrocarbons were analyzed using the GC.FID technique, which is widely used as a routine/screening method for these pollutants. The hydrocarbon levels are reported in mg/kg (ppm level) and their interpretation is carried out for respective hydrocarbon classes as follows:

PAHs in agricultural soils

PAHs were detected in all agricultural soil samples from the Patos–Marinza area. Total PAH concentrations ranged from 0.645 mg/kg in Belin 3 station to 2.555 mg/kg in Zharrëz 2 station, with a mean value of around 1.512 mg/kg. The highest PAH levels were observed in Zharrëz 2, Zharrëz 1 and Marinza 2 stations, with total concentrations of 2.555, 2.344 and 1.914 mg/kg, respectively (Figure 4). The higher level of PAHs in soil were for anthracene, benzo[a]anthracene, perylene, benzo[k]fluoranthrene, indeno[1,2,3-cd]pyrene, phenanthrene and chrysene (Figure 5). Several high molecular weight PAHs were detected, including benzo[a]anthracene, chrysene, benzo[b]fluoranthrene, benzo[k]fluoranthrene, indeno[1,2,3-cd]pyrene, dibenzo[a,b] anthracene and benzo[ghi]perylene. Their presence is important because high molecular weight PAHs are more persistent in soil and have stronger adsorption to organic matter and fine particles.

The highest individual PAH values were found for indeno[1,2,3-cd]pyrene in Zharrëz 1 at 0.656 mg/kg, perylene in Zharrëz 1 and Zharrëz 2 at 0.635 and 0.625 mg/kg, phenanthrene in Marinza 1 at 0.645 mg/kg, anthracene in Marinza 2 at 0.635 mg/kg, and benzo[b]fluoranthrene in Kuman 3 at 0.635 mg/kg. This distribution suggests mixed contamination sources, including petroleum residues, combustion emissions, deposition of contaminated dust and possible irrigation or flooding with polluted surface waters.

Table 2. PAH data in surface water samples from Patos-Marinza area

	Soil, mg/kg (ppm)			
	Mean	**Min**	**Max**	**STDEV**
Acenaftilene	0.005	0.000	0.051	0.016
Fluorene	0.013	0.000	0.082	0.029
Phenantrene	0.151	0.000	0.645	0.201
Anthracene	0.189	0.000	0.635	0.182
Pyrene	0.117	0.000	0.553	0.177

Benzo[a]anthracene	0.189	0.000	0.533	0.197
Chrysene	0.144	0.000	0.369	0.153
Perilene	0.181	0.000	0.635	0.252
Benzo[b]fluoranthrene	0.097	0.000	0.635	0.208
Benzo[k]fluoranthrene	0.173	0.000	0.563	0.192
Indeo[123cd]Pyrene	0.155	0.000	0.656	0.194
Dibenzo[ab]Anthracene	0.056	0.000	0.230	0.083
Benzo[ghi]Perilene	0.042	0.000	0.240	0.079

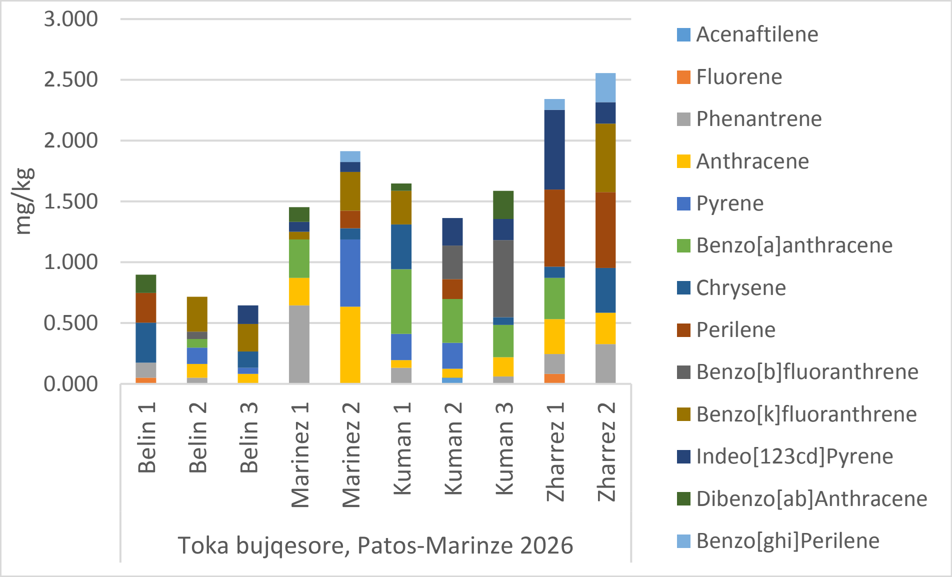

Figure 4. Total of PAH in soil samples from Patos-Marinza area

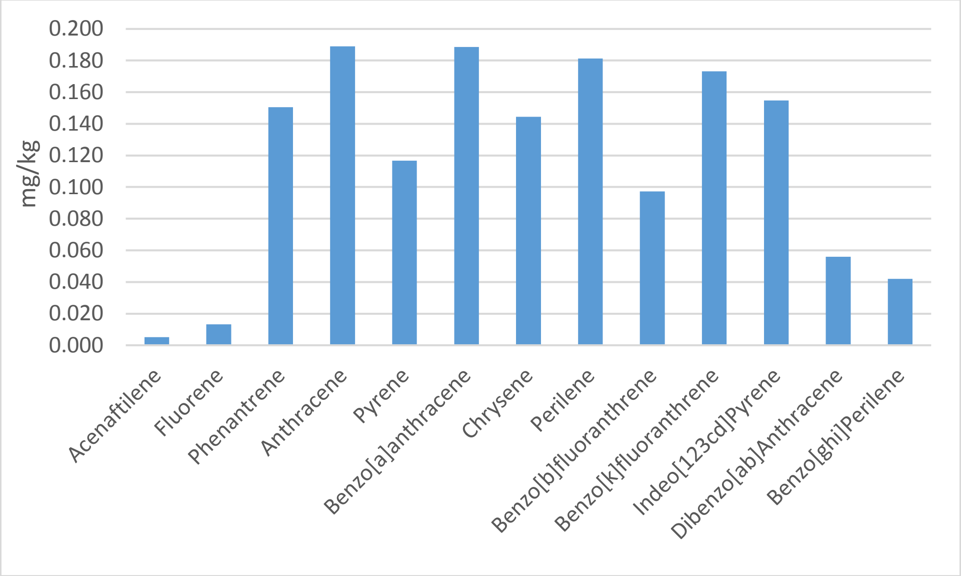

Figure 5. Profile of PAH in soil samples from Patos-Marinza area

In the absence of a single harmonised EU-level value for PAHs in agricultural soils, the results of this study were compared with several international standards and guidelines, including the Dutch Soil Remediation Circular, the Italian D.Lgs. 152/2006, the Canadian Soil Quality Guidelines and the German values for benzo[a]pyrene. For total PAHs, the values measured in the agricultural soils of Patos–Marinza, 0.645–2.555 mg/kg, are lower than the permitted value for the sum of PAHs, 40 mg/kg (Netherlands, 2013). However, some individual PAHs of toxicological importance, such as benzo[a]anthracene, chrysene, benzo[k]fluoranthene and indeno [1,2,3-cd]pyrene, require special attention, as some national standards use much lower limits for individual compounds. Their values are generally lower than the permitted values, but there is a tendency for them to be exceeded at some stations due to higher pollution and their concentration/absorption by agricultural lands.

BTEX in agricultural soils

BTEX concentrations in agricultural soils were relatively higher, particularly in Zharrëz. Total of BTEX concentrations ranged from 0.679 mg/kg in Kuman 2 to 3.370 mg/kg in Zharrëz 2, with a mean value of approximately 1.466 mg/kg. The highest total values were detected in Zharrëz 2 and Zharrëz 1, with concentrations of 3.370 and 3.345 mg/kg, respectively (Figure 6). The most found BTEX compounds in soil were toluene, benzene and ethylbenzene (Figure 7). Mean concentrations were 0.516 mg/kg for toluene, 0.487 mg/kg for benzene and 0.227 mg/kg for ethylbenzene.

The maximum benzene concentration was 1.273 mg/kg in Zharrëz 2, while the maximum toluene concentration was 1.139 mg/kg, also in Zharrëz 2. These results indicate a strong petroleum-related influence in the Zharrëz agricultural soils. BTEX compounds are usually more volatile and degradable than PAHs, so their presence in soil may indicate relatively recent contamination or continuous inputs. Their detection in agricultural soils is significant because they may affect soil quality, microbial activity and potentially crop safety, especially in areas where contaminated irrigation water, atmospheric deposition or direct contact with petroleum residues may occur. Recent Canadian federal guidance specifically addresses BTEX compounds as substances of concern for aquatic life protection, reflecting their environmental relevance.

Table 3. BTEX data on soil samples from Patos-Marinza area, April 2026

	Soil, mg/kg (ppm)			
	Mean	**Min**	**Max**	**STDEV**
Benzene	0.487	0.182	1.273	0.390
Toluene	0.516	0.194	1.139	0.347
p-Xylene	0.135	0.000	0.315	0.115
m-Xylene	0.044	0.000	0.194	0.076
po-Xylene	0.058	0.000	0.255	0.077
Ethylbenzene	0.227	0.000	0.630	0.202

For BTEX, comparison with international standards shows that benzene is the most problematic parameter for regulatory interpretation, due to its toxicity and very conservative limit values in some guidelines.

The maximum benzene concentrations measured in agricultural soils of Patos–Marinza, up to 1.273 mg/kg, are above some residential/agricultural use guideline values, such as the Italian value of 0.1 mg/kg and the Canadian values for coarse/fine soil, while they are close to or above the Dutch intervention value of 1.0 mg/kg. This supports the need for a more detailed risk assessment at the Zharrëz and Marinza stations.

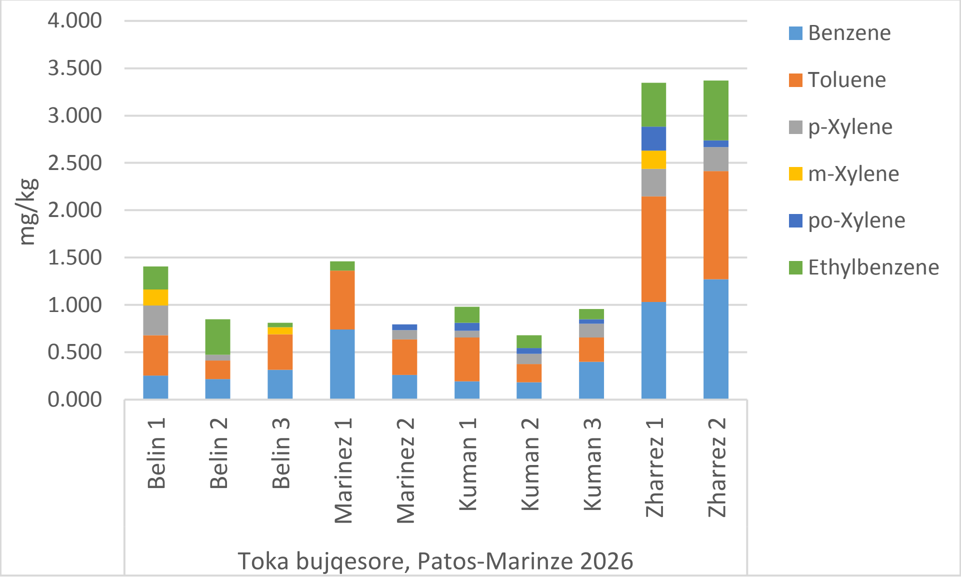

Figure 6. Total of BTEX in soil samples from Patos-Marinza area

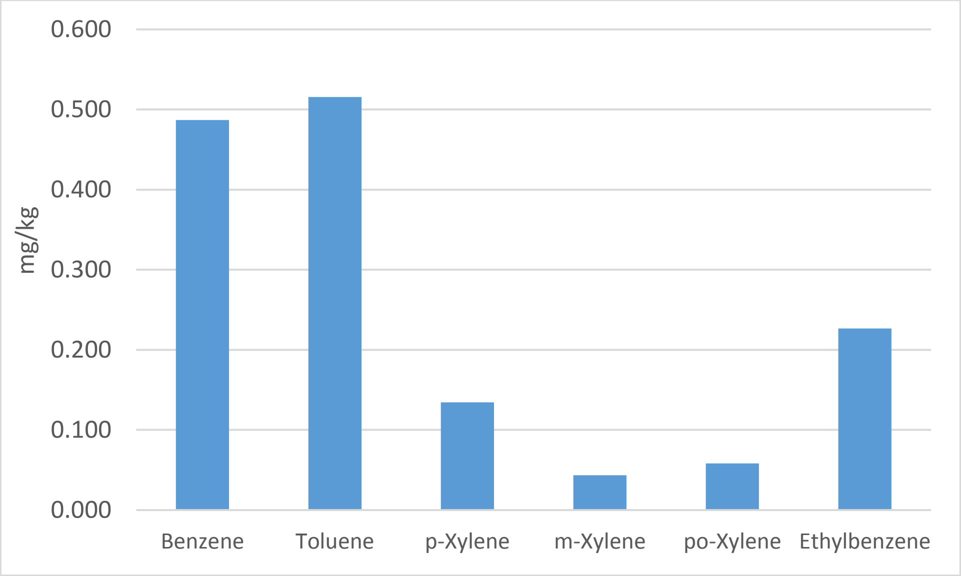

Figure 7. Profile of BTEX in soil samples from Patos-Marinza area

Occurrence of n-alkanes in agricultural soils

The total concentration of n-alkanes in agricultural soils ranged from 0.752 mg/kg in Belin 2 to 2.536 mg/kg in Marinza 2, with a mean value of approximately 1.711 mg/kg.

Relatively high values were also observed in Zharrëz 1, Kuman 1, Zharrëz 2 and Marinza 1 (Figure 8). Agricultural soils showed higher concentrations of n-alkanes, which is expected because soils can retain hydrophobic compounds through adsorption to organic matter and mineral particles.

The most abundant n-alkanes in soil were C18, C16, C20, C22 and C20x. C18 was the dominant compound, with a mean concentration of 0.627 mg/kg and a maximum value of 1.083 mg/kg in Kuman 1. C16 was also important, with a mean of 0.365 mg/kg and a maximum of 0.707 mg/kg in Marinza 2 (Figure 9). The predominance of C16–C22 fractions indicates the presence of petroleum-derived hydrocarbons, lubricants or weathered oil residues. The relatively low contribution of short-chain n-alkanes may be due to evaporation, degradation or lower persistence in the environment.

For n-alkanes, international norms do not make available permitted levels for individuals and/or their sum in agricultural soils due to their natural origin and very low toxicity values, although the presence of long-chain n-alkanes can pose a problem mainly due to their strong absorption by organic matter, low solubility in water and slow evaporation.

Table 4. Aliphatic hydrocarbons in soil samples from Patos-Marinza area

	Soil, mg/kg (ppm)			
	Mean	**Min**	**Max**	**STDEV**
C10	0.024	0.000	0.239	0.076
C12	0.014	0.000	0.068	0.029
C14	0.093	0.000	0.353	0.131
C16	0.365	0.148	0.707	0.170
C18	0.627	0.182	1.083	0.306
C20	0.210	0.000	0.638	0.242
C20x	0.114	0.000	0.388	0.153
C22	0.119	0.000	0.376	0.149
C24	0.092	0.000	0.270	0.111
C26	0.054	0.000	0.360	0.116

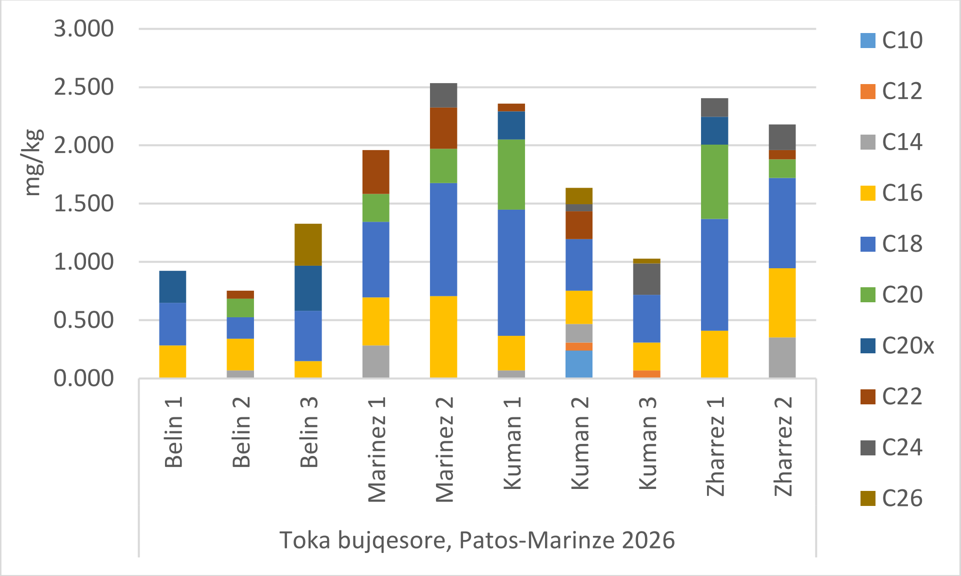

Figure 8. Total of n-alkane in soil samples from Patos-Marinza area

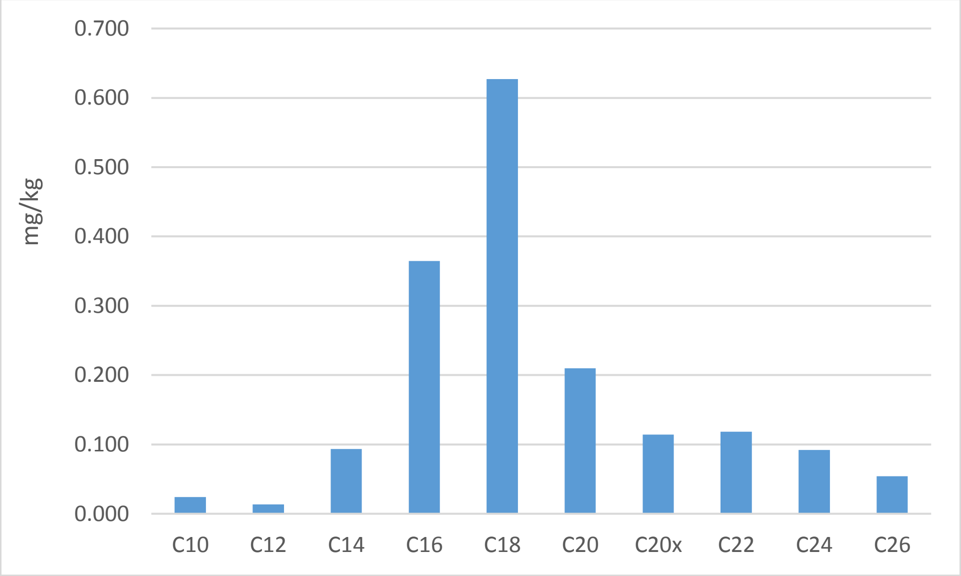

Figure 9. Profile of n-alkane in soil samples from Patos-Marinza area

Conclusions

The presence of PAHs and n-alkanes in soil indicates the possibility of contaminant transfer between environmental compartments. Surface runoff, irrigation, flooding, atmospheric deposition, contaminated dust and direct contact with petroleum residues may all contribute to the observed contamination. In the Patos–Marinza area, where oil extraction and petroleum-related activities are historically important, these pathways are environmentally possible. The results indicate that the Patos–Marinza area is affected by mixed hydrocarbon contamination of both petrogenic and pyrogenic origin. BTEX and n-alkanes are typical indicators of petroleum-related contamination, while PAHs may originate from both petroleum residues and incomplete combustion processes. The coexistence of BTEX, PAHs and n-alkanes in the same samples supports the interpretation of multiple and continuing anthropogenic inputs on this area.

From an environmental viewpoint, the most concerning findings are the elevated benzene levels, the presence of high molecular weight PAHs, and the high combined hydrocarbon loads in agricultural soils of Zharrëz and Marinza soil samples. Based on international guidelines for found levels of benzene and PAH compounds such as benzo[a]anthracene, chrysene, benzo[b]fluoranthrene, benzo[k]fluoranthrene, indeno[1,2,3-cd]pyrene and dibenzo[a,b]anthracene require attention due to their persistence and toxicological relevance.

The results show that hydrocarbon contamination is not uniformly distributed across the study area, whereas Zharrëz stations are the most affected agricultural soil sites. These findings indicate that agricultural land located near petroleum infrastructure should be monitored regularly, especially where soils are used for crop production. Remediation measures such as bioremediation, phytoremediation, soil amendment with organic materials, microbial stimulation and targeted removal of highly contaminated soil fractions should be considered after detailed site-specific assessment. Future research should include seasonal monitoring, deeper soil profiles, groundwater and irrigation water analysis, total petroleum hydrocarbons, soil organic matter, grain-size distribution, microbial activity indicators, plant uptake studies and confirmatory GC/MS analysis for selected priority compounds. These steps are necessary to better evaluate ecological risk, agricultural implications and possible exposure pathways for local communities.

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