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POLYCYCLIC AROMATIC HYDROCARBONS (PAHs) IN WATER AND SEDIMENTS OF THREE MAJOR RIVERS: SPATIAL DISTRIBUTION, POLLUTION SOURCE APPORTIONMENT, ECOLOGICAL RISKS AND HUMAN HEALTH IMPACTS

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Veszprém, Hungary
2025

INTRODUCTION

Freshwater is a valuable and scarce resource for both individuals and ecosystems. The protection and preservation of freshwater are increasingly important with the drive to promote food security and sustainable development growth agenda for life below water. The majority of the world's biggest cities were constructed on or near regions of freshwater, mostly rivers. Most research on aquatic systems is primarily concerned with the effects of anthropogenic activities and natural phenomena, such as volcanism and biological processes, on both human health and ecology. The emission levels of several anthropogenic toxins, including Polycyclic Aromatic Hydrocarbons (PAHs), have grown in the environment due to population expansion and associated increases in industrial, agricultural, and urban activities. These chemicals have attracted significant worldwide interest due to their toxicity, persistence, bioaccumulation, and potential adverse health effects on living beings. Thus, the European Union (EU) and the United States Environmental Protection Agency (USEPA) have identified 16 PAHs as priority pollutants among the hundreds of PAHs in the environment. PAHs could be bounded to soil particles and could also adsorb on suspended particulate matter when entering the water and ultimately settle into the sediment. This is due to their high octanol–water partition coefficient and hydrophobic lipophilicity. Consequently, river sediments are susceptible to PAHs accumulation and release. Moreover, they are commonly used as an indicator for detecting probable emission sources and determining the exposure risk of PAHs to benthic biotas. Therefore, the environmental fate and the possible ecological risk related to PAHs are serious matters of public concern.

1. SIGNIFICANCE AND SCOPE OF THE TOPIC

The effluents from industrial operations and wastewater treatment plants significantly impact river ecosystems. These discharges pose a serious threat to aquatic life by degrading water and sediment quality through various pollutants. In Europe, the WFD mandates European Union member states to achieve satisfactory quantitative and qualitative assessments of all water bodies. In Asia, specifically in Iraq, increasing pollution sources, including oil refineries, automobiles, routine gas and fuel combustion activities, and gasoline- and diesel-powered generators, have contributed to the degradation of water and sediment quality in two major and historically significant rivers, the Tigris and Euphrates. Thus, the study aims to:

1- Monitoring the presence of 16 PAHs contaminants in water and sediment across all investigated rivers.
2- Determining the primary sources of 16 PAHs contamination across all investigated rivers.
3- Examining the compositional profiles of 16 PAHs in all rivers.
4- Evaluating the ecological risks associated with 16 PAHs in all rivers.
5- Identifying and quantifying the Incremental Lifetime Cancer Risk (ILCR) for both adults and children across all rivers.

In Hungary, the specific aims in the Danube River are as follows:

- Conduct a spatial and temporal assessment of 16 PAHs contaminants in the water and sediment of the Danube River in Hungary.
- Identify the primary sources of 16 PAHs contaminants in the Danube River.
- Evaluate the eco-toxicological risks associated with PAHs in the Danube River.
- Assess and quantify the Incremental Lifetime Cancer Risk (ILCR) for both adults and children exposed to PAHs in the Danube River.

- Compare the pollution levels with international guidelines and other reported global pollutions.

In Iraq, given the limited number of studies on PAHs pollution in the Tigris and Euphrates Rivers basins, the aims are:

- Investigate the 16 PAHs pollutants in areas near oil refineries along the Tigris River by measuring contamination levels before and after major refineries, including Baiji, Kirkuk, Al-Siniyah, Qayyarah, Al-Kasak, Daura, South Refineries Company, and Maysan.
- Conduct a spatial assessment of PAHs contamination in the water and sediment of the Tigris River.
- Investigate 16 PAHs in both water and sediment samples along the Euphrates River.
- Assess the ecological risk of 16 PAHs in both the Tigris and Euphrates Rivers.
- Analyze the composition profiles of 16 PAHs in the Tigris and Euphrates Rivers.
- Determine the contribution rates of various pollution sources in the Tigris and Euphrates Rivers.
- Assess the potential health and environmental risks of PAHs pollution in the Tigris and Euphrates Rivers.
- Compare the pollution levels with international guidelines and reported global pollution.

2. SAMPLINGS AND METHODS

2.1 Samples collection and pretreatment in Danube River

Water and sediment samples were collected monthly (two samples per month) from February 2022 to February 2023, spanning a 12-calendar-month period. Sediments were typically collected after water sampling to prevent disturbance and resuspension of the sediment into the water. Water samples were obtained from depths of 5 to 30 cm using 1 L brown glass containers that had been previously cleaned by acetone and methanol then heated to 100 °C. The samples were temporarily stored in refrigerated containers with crushed ice until they were transported to the laboratory and kept at -20 °C. Upon arrival at the laboratory, the water samples were filtered using a 0.45 µm glass fiber membrane. Sediment samples were collected from the riverbed at depths of 0–10 cm using a stainless-steel grab sampler and placed in clean polyethylene bags. These samples were sieved through a 100-mesh sieve to remove roots, debris, and large particles. The sieved sediments were dried at 25 °C and then ground. Finally, the dried sediments were stored in a freezer at –20 °C for further analysis.

2.1.1 PAHs Extraction procedures for Danube River

2.1.1.1 Water sample extraction procedure for Danube River

Solid-phase extraction (SPE) was used to extract one liter of filtered water samples for analysis. An SPE membrane was pre-washed with six milliliters of dichloromethane (DCM) before conditioning (activation) with six milliliters of methanol, six milliliters of ultrapure water, and an additional ten milliliters of methanol. A ten-microliter surrogate standard mixture solution (naphthalene-d_8, anthracene-d_{10}, fluoranthene-d_{10}, perylene-d_{12}) was added to one liter of the water sample to enrich it. The sample was then passed through the SPE membrane at a flow rate of 3 mL/min. Once extraction was complete, a vacuum pump was used to dry the column. Six milliliters of dichloromethane was added to soak the column for 5 minutes before eluting the sample into a clean glass test tube. The eluate was then concentrated to 0.5 mL using nitrogen gas, after which ten microliters of a standard mixture solution was added. Finally, the samples were analyzed using gas chromatography-mass spectrometry (GC–MS).

2.1.1.2. Sediment sample extraction procedure for Danube River

The freeze-dried sediment samples were pulverized using a mortar and pestle and sieved through a 100-mesh sieve to remove large particles. The dried and homogenized sediment samples were placed in brown glass vials for further laboratory analysis. A 2-gram sample was weighed, and five milliliters of an acetone/n-hexane (1:1, v/v) solution along with a standard surrogate solution were added to the test tube. The sample was vortexed for 60 seconds, followed by ultrasonic extraction in a water bath for 15 minutes. Afterward, the test tubes were centrifuged for 20 minutes at 2000 rpm to separate the solid and liquid phases. The supernatant was then transferred to a clean test tube using a Pasteur pipette. Five milliliters of a 1:1 mixture of acetone and n-hexane was added to each sample. The extracts were combined in a single test tube, and activated copper was added for desulfurization. Anhydrous sodium sulfate was then added to remove residual water, followed by concentration to 0.5 milliliters using a nitrogen-blowing concentrator. Finally, an internal standard solution was added for GC–MS analysis.

2.2. Samples collection and analysis for Tigris River

During the sampling campaign from July to December 2022, each location was sampled six times. Water samples were collected between 20 and 40 cm below the surface using a pre-cleaned stainless-steel container. Samples were spiked with surrogates (naphthalene-d_8, anthracene-d_{10}, fluoranthene-d_{10}, and perylene-d_{12}) as the PAHs recovery standard, sealed in five-liter glass containers, transported to the laboratory, and refrigerated at 4°C until further analysis. Five liters of surface water were filtered through a 0.45 µm glass fiber membrane and a methanol-activated solid-phase extraction (SPE) membrane to isolate PAHs for analysis. The PAH-containing SPEs were wrapped in aluminum foil and refrigerated until further measurements.

Sediment samples were collected using a grab sampler, with three samples taken at each site (0–10 cm depth) and then combined in dark glass bottles for transport. SPE membranes were eluted twice with dichloromethane-ethyl acetate and ethyl acetate solutions. The extracts were pooled, dried over anhydrous sodium sulfate, concentrated with a rotary evaporator, and redissolved in one milliliter of n-hexane.

For sediment extraction, four grams of freeze-dried sediment were weighed, sieved with a 100-mesh stainless steel sieve, spiked with surrogates, and placed in an extraction tube containing 50 mL of a 1:1 acetone-hexane mixture. Extraction was performed using a microwave digestion system, with the temperature rising from 25 to 120°C at 8°C per minute and held for 20 minutes. Samples were then centrifuged for 20 minutes at 1000 rpm. The supernatant was passed through anhydrous sodium sulfate, then subjected to extraction and purification in a glass chromatography column. The final extract was concentrated to approximately 2 mL, after which 1 mL of n-hexane was added for analysis.

2.3. Samples collection and analysis for Euphrates River

Surface water and sediment samples were collected monthly from March 2022 to July 2022, with five measurements taken at each site during this period. Surface water samples were taken from a depth of 10–30 cm below the water's surface using a pre-cleaned stainless-steel container. Each sample was spiked with 1 µg of surrogates, sealed in 6 L glass containers, and transported to the laboratory within a day, where they were stored at 4 °C until analysis. For PAHs separation, 6 L of surface water was filtered through a 0.45 µm glass fiber membrane, followed by a methanol-activated solid-phase extraction (SPE) membrane to isolate PAHs. The SPE membrane containing PAHs was wrapped in foil and cooled for further analysis.

Sediment samples were collected using a pre-cleaned grab sampler and stored in sealed bags. At each site, sediment samples (0–10 cm) were taken three times, combined, and stored in dark glass bottles. Samples were transported to the laboratory for further analyses.

For PAHs extraction from the SPE membrane, dichloromethane-ethyl acetate and ethyl acetate solutions were used. The combined extracts were then dried over anhydrous sodium sulfate, concentrated with a rotary evaporator, and redissolved in 1 mL of n-hexane.

For sediment extraction, approximately 2 g of freeze-dried sample, sieved through a 100-mesh stainless steel screen and spiked with 1 µg of surrogates, was transferred to an extraction tube containing 25 mL of acetone-hexane (1:1) and extracted using a microwave digestion system. The temperature was raised from 25 °C to 120 °C at a rate of 8 °C/min and held for 20 min. Samples were then centrifuged at 2000 rpm for 20 min, and the supernatants were dried over anhydrous sodium sulfate, purified through a glass chromatography column, and evaporated to approximately 2 mL. Finally, 1 mL of n-hexane was added for measurement. PAHs measurements were performed using GC–MS.

2.4.Gas chromatography-mass spectrometry (GC–MS) and Total organic matter (TOM)

PAHs were measured using GC–MS (Agilent 6890 N with a 5975C mass selective detector, Agilent Technologies, USA). Helium served as the carrier gas at a flow rate of 1.5 mL/min through an HP-5MS column (30 m × 0.32 mm × 0.25 µm). Selective ion monitoring (SIM) mode was used for quantitative analysis. The injector temperature was set to 300 °C. The oven temperature program was as follows: initial temperature of 100 °C held for 1 minute, then increasing to 300 °C at a rate of 8 °C per minute, where it was held for 39 minutes. Triplicate measurements were taken for each sample, yielding a relative standard deviation of less than 10.2% for Danube River and <6% for Tigris and Euphrates Rivers. Total organic matter (TOM) was quantified by determining the weight reduction in sediment samples that had been oven-dried at 105 °C for 48 hours, followed by combustion at 550 °C for 2 hours.

2.5. Quality Control (QC) and Quality Assurance (QA)

2.5.1. Danube River

Quality control measures included triplicate samples, matrix spike standards, calibration standards, procedural blanks, and detection limits. Prior to each measurement, the glassware was cleaned using ultrasonic cleaners, followed by washing with acetone, n-hexane, methanol, and dichloromethane to eliminate background contamination, and then dried at 105 °C before use. The concentrations of 16 PAHs in sediment samples were determined using the dry weight approach. LOD were established based on analyte concentration and a 3-fold signal-to-noise ratio. LODs ranged from 0.02 to 0.59 ng/L for water and from 0.37 to 0.96 ng/g (dry weight) for sediment. PAHs recoveries were assessed by spiking water and sediment samples with standard solutions. Each sample analysis included a procedure blank (solvent), a spiked blank (standards added to solvent), and triplicate samples. Analysis of method blanks confirmed the absence of detectable PAHs contamination. Recovery ranges for the 16 PAHs were 91.5% ± 4.3% to 104.1% ± 7.6% for water samples and 86.8% ± 5.5% to 99.2% ± 6.2% for sediment samples. For spiking standards, recovery ranges were 92.8% ± 4.5% to 109.7% ± 6.9% for water samples and 90.5% ± 8.3% to 97.4% ± 4.4% for sediment samples. Reference and blank samples were measured to confirm analysis accuracy. Each sample was measured in triplicate, yielding a relative standard deviation between 1.7% and 10.4%, well within the acceptable limit (< 25%). Mean values are presented for all measurements. The data in this study were tested for normality using the Kolmogorov-Smirnov test at a significant level of 0.05.

2.5.2. Tigris River

Glassware was heated to 100 °C and cleaned with acetone, methanol, and dichloromethane before each measurement to eliminate background contamination. Quantitative standards for 16 PAHs in water samples were established using external standard techniques. Linearity correlation values for the 16 PAHs monomers ranged from 0.997 to 0.998. PAHs levels in sediment samples were determined using the dry weight method. LOD were calculated based on analyte concentration, using a 3:1 signal-to-noise ratio. The LOD ranged from 0.06 to 0.35 ng/L for water and from 0.13 to 0.75 ng/g dry weight (dw) for sediment. For recovery analysis, the 16 PAHs standard solutions were spiked into water and sediment samples. Each sample analysis included a method blank (solvent), a spiked blank (standards added to solvent), and sample triplicates. Method blank analysis confirmed the absence of detectable PAHs contamination. Recovery ranges for water and sediment samples were 93.2% to 100% and 85.3% to 98.8%, respectively, while spiking standard recoveries ranged from 94.5% to 110.4% in water and 89.3% to 96.6% in sediment. Blank and reference samples were also measured to verify accuracy, and each sample was analyzed in triplicate, resulting in a relative standard deviation of less than 4%. Mean values are reported in this study. The Kolmogorov-Smirnov normality test was applied to all data at a significant level of 0.05.

2.5.3. Euphrates River

Prior to each experiment, glassware was heated to 150 °C and rinsed with methanol, acetone, and dichloromethane to minimize background contamination. Quantitative standards for PAHs in the water samples were determined using external standard methods. For the 16 PAHs, the linear correlation coefficients ranged between 0.998 and 0.999. PAHs concentrations in sediment samples were measured as dry weight. LOD were calculated based on analyte concentration using a three-fold signal-to-noise ratio. LOD values for water samples ranged from 0.04 to 0.28 ng/L, while those for sediment samples ranged from 0.09 to 0.65 ng/g (dry weight, dw). Recovery rates for the 16 PAHs standards ranged from 90.4% to 100% for water samples and from 81.4% to 97.6% for sediment samples. Recovery rates for the spiking standards (surrogates) were 92.6%–106.8% for water samples and 85.4%–95.3% for sediment samples. PAHs concentrations were corrected for recovery. Both water and sediment samples were analyzed in triplicate, and results are presented as mean values. All data in this study were subjected to a normality test using the Kolmogorov-Smirnov method with a significance level of 0.05.

2.6. Eco-toxicological concerns and Incremental Lifetime Cancer Risk (ILCR) for River's sediment

PAHs levels in sediments were evaluated according to sediment quality guidelines (SQGs). By comparing the concentration of each PAHs to the Effect Range Low (ERL) and Effect Range Median (ERM) values, the ecological risk posed to aquatic species from exposure to sediment-bound PAHs was determined. The SQGs classify chemical concentrations into three ranges based on potential biological effects: 1) minimal effects range, where biological effects are rare (<ERL), 2) possible effects range, where biological effects occur occasionally (≥ERL and <ERM), and 3) probable effects range, where biological effects are frequent (≥ERM).

To compare the carcinogenicity of PAHs with that of benzo[a]pyrene (BaP), the toxic equivalency factor (TEF) approach was used to calculate the BaP equivalency (BaPeq) of each PAH. BaP was selected as a reference due to its high carcinogenicity and was assigned a TEF value of one, allowing the carcinogenicity of other PAHs to be estimated relative to BaP. Based on their relative carcinogenicity to BaP, each PAHs has a unique TEF value. The formulas below were used to calculate the toxic equivalent quotient (TEQ) for each sampling location in this study:

$$\mathrm{BaPeq_i} = (\mathrm{PAH_i} \times \mathrm{TEF_i}) \qquad \textbf{(1)}$$

$$\mathrm{TEQ} = \sum_1^n (\mathrm{PAH_i} \times \mathrm{TEF_i}) \qquad \textbf{(2)}$$

where PAH_i is the PAH concentration and TEF_i is the toxic equivalency factor.

Using the USEPA's ILCR model, which examined the three main routes of exposure to contaminants (ingestion, dermal contact, and inhalation), a risk assessment to PAHs in river sediments was performed. This assessment was required because of people's daily reliance on the region's aquatic resources. ILCR is used to estimate the human cancer risk posed by exposure to environmental PAHs. The overall carcinogenic risk was determined by summing up the hazards associated with the three routes of exposure. Table 1 and equations (3, 4, 5, and 6) respectively explain the ILCR assessment parameters and model formulations.

$$\mathrm{ILCR_{ingestion}} = \mathrm{CS} \times \mathrm{IR_{ingestion}} \times \mathrm{EF} \times \mathrm{ED} \times \left(\mathrm{CSF_{ingestion}} \times \sqrt[3]{\frac{\mathrm{BW}}{70}}\right) \times (\mathrm{BW} \times \mathrm{AT} \times 10^{6})^{-1} \quad \textbf{(3)}$$

$$\mathrm{ILCR_{inhalation}} = \mathrm{CS} \times \mathrm{IR_{inhalation}} \times \mathrm{EF} \times \mathrm{ED} \times \left(\mathrm{CSF_{inhalation}} \times \sqrt[3]{\frac{\mathrm{BW}}{70}}\right) \times (\mathrm{BW} \times \mathrm{AT} \times \mathrm{PEF})^{-1} \quad \textbf{(4)}$$

$$\mathrm{ILCR_{dermal\ contact}} = \mathrm{CS} \times \mathrm{SA} \times \mathrm{AF} \times \mathrm{ABS} \times \mathrm{EF} \times \mathrm{ED} \times \left(\mathrm{CSF_{dermal\ contact}} \times \sqrt[3]{\frac{\mathrm{BW}}{70}}\right) \times (\mathrm{BW} \times \mathrm{AT} \times 10^{6})^{-1} \quad \textbf{(5)}$$

$$\text{Carcinogenic risk} = \mathrm{ILCR_{ingestion}} + \mathrm{ILCR_{dermal\ contact}} + \mathrm{ILCR_{inhalation}} \quad \textbf{(6)}$$

CSF is the carcinogenic slope factor, which is represented in units of (mg $\mathrm{kg^{-1}day^{-1}})^{-1}$. According to the USEPA, the CSF concentrations of BaP for the three exposure pathways are 25, 7, 3 and 3.85 mg/kg/$\mathrm{day^{-1}}$. CS is the total PAHs concentrations that transformed to hazardous equivalents of BaP using the Toxic Equivalence Factor (TEF) (in ng/g). Calculation of the ILCR relies heavily on the detection of PAHs as BaP-equivalent concentrations using the TEF of each PAHs relative to BaP.

The total ILCR is equal to the sum of three routes: skin contact, oral consumption, and inhalation. If the ILCR is less than $1/10^6$, it is deemed inconsequential; if it is more than $1/10^4$, there is a reason for serious concerns.

Table 1 Parameters descriptions used for ILCR model

Parameter	Description	Unit	Adults	Children
ABS	Dermal-Absorption-Factor	unitless	0.13	0.13
AF	Dermal-Adherence-Factor	mg/cm^2	0.07	0.2
AT	Average-Time(70years_365 days/year)	Days	25,550	25,550
BW	Body-Weight	Kg	70	15
ED	Exposure-Duration	Years	20	6
EF	Exposure-Frequency	days/ year	350	350
IR ingestion	Ingestion-Rate	mg/day	100	200
IR inhalation	Inhalation-Rate	m^3/day	20	10
PEF	Particular-Emission-Factor	m^3/kg	1.36×10^9	1.36×10^9
SA	Dermal-Surface-Area-Exposure	cm^2	5700	2800

3. NEW SCIENTIFIC FINDINGS

In the **Danube River**, I found the following points:

-I observed significant seasonal fluctuations in PAHs concentrations in water, ranging from 224.8 ng/L in summer to 365.8 ng/L in winter. Similarly, PAHs concentrations in sediment samples varied, from 316.7 ng/g (dry weight) in summer to 422.9 ng/g (dry weight) in winter.

-According to the European Drinking Water Directive, PAHs levels exceeded the permitted limit of 100 ng/L, showing a 124.8% increase in summer and a 265.8% increase in winter.

-I concluded that the primary sources of PAHs were anthropogenic, mainly from pyrolytic and pyrogenic processes, with pyrogenic sources being more dominant.

-Except for Acy and FI concentrations, the eco-toxicological assessment of the Danube River environment showed no significant PAHs pollution in sediments, suggesting a low likelihood of negative biological impacts and a low ecological risk.

-ILCR for both children and adults marginally higher than the limit ($1/10^4$) in all seasons, with the highest values recorded in spring, followed by winter, indicating a concerning public health issue.

In the **Tigris River**, I found the following results:

-The 16 PAHs concentrations ranged from 567.8 to 3750.7 ng/L in water and from 5619.2 to 12795.0 ng/g in sediment. Water samples near the South Refineries Company recorded the highest PAHs concentrations, while sediment samples from the Baiji oil refinery showed the highest levels.

-I observed that HMWPAHs (5-6 rings) had the highest percentages in both water and sediment samples, ranging from 49.41% to 81.67% for water and from 39.06% to 89.39% for sediment.

-I concluded that the majority of the 16 PAHs measured in water and sediment samples from the Tigris River were derived from pyrogenic sources.

-For Sediment Quality Guidelines (SQGs), most sites showed a possible effect range with occasional biological impacts due to elevated PAHs concentrations in sediment samples. The calculated ILCR value indicated a high risk, with potential adverse health effects, including cancer.

In the **Euphrates River**, I found the following points:

-I observed that PAHs contamination increased along the river's flow direction due to rising non-point source pollution.

-I found that 5-6 ring PAHs were dominant in water and sediment samples, with averages of 42% and 50%, respectively.

-Carcinogenic PAHs constituted 46% and 55% of the total measured compounds in water and sediment samples, respectively, highlighting potential ecological and human health risks.

-For Sediment Quality Guidelines (SQGs), most sites exhibited an effect range between low and medium. The calculated ILCR for adults and children was in the range of 10^{-2} to 10^{-3}, which is 3-6 times higher than reported in the literature.

-I concluded that PAHs source identification suggests the PAHs pollution originates from petroleum product consumption, which is expected given the increasing use of private cars and home electricity generators

PUBLICATION LIST

Published articles related to thesis research.

1- **Grmasha, R. A.,** Stenger-Kovács, C., Al-Sareji, O. J., Al-Juboori, R. A., Meiczinger, M., Andredaki, M., ... & Al-Ansari, N. (2024). Temporal and spatial distribution of polycyclic aromatic hydrocarbons (PAHs) in the Danube River in Hungary. Scientific Reports, 14(1), 8318. **D1, IF=3.8**

2- **Grmasha, R. A**., Stenger-Kovács, C., Bedewy, B. A. H., Al-Sareji, O. J., Al-Juboori, R. A., Meiczinger, M., & Hashim, K. S. (2023). Ecological and human health risk assessment of polycyclic aromatic hydrocarbons (PAH) in Tigris River near the oil refineries in Iraq. Environmental Research, 227, 115791. **D1, IF=8.3**

3- **Grmasha, R. A.,** Abdulameer, M. H., Stenger-Kovács, C., Al-Sareji, O. J., Al-Gazali, Z., Al-Juboori, R. A., ... & Hashim, K. S. (2023). Polycyclic aromatic hydrocarbons in the surface water and sediment along Euphrates River system: Occurrence, sources, ecological and health risk assessment. Marine Pollution Bulletin, 187, 114568 **Q1, IF=7.1.**

Conference oral presentation related to thesis research

1-**Ruqayah Ali Grmasha,** Csilla Stenger-Kovács, Osamah J. Al-sareji, Raed A. Al-Juboori, Mónika Meiczinger, Marwan H. Abdulameer, Zaid Al-Gazali, Khalid S. Hashim, The level of Polycyclic aromatic hydrocarbons (PAHs) in the main water bodies in Iraq: An update status, VII th, International Symposium-2023 "Environmental Health and Biosecurity Strategy” May 4th – 5th, 2023 Óbuda University Budapest, Hungary

2-**Ruqayah Ali Grmasha,** Csilla Stenger-kovács, Osamah J. Al-sareji, Mónika Meiczinger, Raed A. Al-Juboori, Polycyclic aromatic hydrocarbons (pahs) levels in three different rivers. 15th ICEEE-2024 Online International Annual Conference November 21 - 22, 2024 Obuda University, Budapest – Hungary Theme: “Global Environmental Development & Sustainability: Research, Engineering & Management”.

SCIENTOMETRIC DATA

Number of publications which are base of the PhD thesis: **3**
Total number of publications: **26**

Impact factors are base of the PhD thesis: **19.2**
Total impact factor: **91.96**

H-index (Google scholar): **12**

Veszprem, March 09, 2025