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# Assessing the impact of organic and inorganic micropollutants released from a wastewater treatment plant on humans and aquatic environment, Al-Hoceima city, Morocco

Yahya El Hammoudani [a,*], Khadija Haboubi [a], Abdelhak Bourjila [a], Iliass Achoukhi [a], Chaimae Benaissa [b], Hatim Faiz [a], Abdelaziz Touzani [a], Mohamed Moudou [a], Maryam Esskifati [a], Mustapha El Boudammoussi [a], Kawthar El Ahmadi [a], Chaimae Haboubi [a], Imane Dira [a], Aouatif El Abdouni [a], Fouad Dimane [a]

[a] *National School of Applied Sciences of Al-Hoceima, Department of Energy and Environmental Civil Engineering / Engineering Sciences and Applications Laboratory / Abdelmalek Essaâdi University, Tetouan, Morocco*

[b] *Faculty of Science and Technology of Tangier, Department of Earth Sciences / Geosciences research team on natural risks / Abdelmalek Essaâdi University, Tetouan, Morocco*

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ABSTRACT

Wastewater contains a variety of compounds qualified as pollutants. These undergo incomplete treatment in wastewater treatment plants. The objective of this study is to determine the potential impacts on humans and aquatic environment of 46 organic and inorganic micropollutants using the USE-tox® model. The concentrations used in this study are obtained by analyzing raw and treated wastewater from the wastewater treatment plant of the city of Al-Hoceima, Morocco. The total human health impact score is $10^{-2}$, generally varying between $10^{-3}$ and $10^{-9}$. Ba, Hg, Zn and Cd had the highest score with a percentage of 92 % of the total score. For the aquatic environment, impact was estimated for 25 compounds. Pyrene, Anthracene, Benzo(a)Anthracene, Fluoranthene and PCB-77 were the major contributors with an impact ranging from 3.43E+02–1.21E+01 PDF.m$^3$.d. With a value of 3.43E+02, Pyrene had the highest impact, contributing 73 % by itself.

## 1. Introduction

The release of micropollutants (MPs) from wastewater treatment plant (WWTP) into the environment is a primary issue related to micropollutants in sanitation. These discharges have been for a long considered a pivotal contributor to the introduction into the environment [1–4]. It has been proven by previous works that micropollutants are present in treated wastewaters, and also contamination of fresh and sea waters [1,5,6].

The removal efficiency of micropollutants in WWTP is satisfactory, even if they are not well adapted to remove these compounds [7–10]. This elimination is essentially done by adsorption on sludge (hydrophobic substances), by biological degradation, or by an abiotic degradation for some substances [11,12]. However, some substances are only partially or not at all absorbed or degraded. They can be described as "refractory" to biological treatment. As a result, some micropollutants are still present in discharges from conventional wastewater treatment plants at significant concentrations [13,14].

The diffusion of micropollutants (MPs) into the environment is facilitated by wastewater treatment plants. It is therefore important to evaluate the effects of these compounds. Inorganic micropollutants such as heavy metals (Lead, Mercury, Cadmium, etc.) and arsenic can seriously damage human health by contaminating drinking water and aquatic ecosystems, leading to neurological, cardiovascular and kidney problems, as well as posing risks to aquatic life [15–18]. Organic micropollutants, including pharmaceuticals, pesticides, industrial compounds (PCBs, PAHs, PFCs) and microplastics, can disrupt aquatic ecosystems and harm human health when consumed in contaminated water or food, contributing to antibiotic resistance, endocrine disruption, cancer risks and environmental damage [19]. Monitoring and treatment of these micropollutants is mandatory to protect humans and aquatic environments from their harmful effects. The ratios Predicted

* Corresponding author.
*E-mail address:* elhammoudani5@gmail.com (Y. El Hammoudani).

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**Table 1**
Micropollutants considered and its distribution.

| Micropollutants | | Raw wastewater | Treated wastewater |
|---|---|---|---|
| PAHs | Acenaphthene | + | + |
| | Acenaphthylene | + | + |
| | Anthracene | + | + |
| | Benzo (a) anthracene | + | + |
| | Benzo (a) pyrene | + | + |
| | Benzo (b) Fluoranthene | + | + |
| | Benzo (g,h,i) pyrelene | + | + |
| | Benzo (k) Fluoranthene | + | + |
| | Chrysene | - | - |
| | Dibenzo (a,h) Anthracene | - | - |
| | Fluoranthene | + | + |
| | Fluorene | + | + |
| | Indeno (1,2,3,cd) Pyrene | + | + |
| | Naphthalene | + | + |
| | Phenanthrene | + | + |
| | Pyrene | + | + |
| PCBs | PCB−28 | - | - |
| | PCB−52 | - | - |
| | PCB−77 | + | + |
| | PCB−81 | + | + |
| | PCB−101 | - | - |
| | PCB−105 | + | + |
| | PCB−114 | + | + |
| | PCB−118 | + | + |
| | PCB−123 | - | - |
| | PCB−126 | + | + |
| | PCB−138 | - | - |
| | PCB−153 | - | - |
| | PCB−156 | + | + |
| | PCB−157 | - | - |
| | PCB−167 | + | + |
| | PCB−169 | + | + |
| | PCB−180 | - | - |
| | PCB−189 | + | + |
| HMs | Cu | + | + |
| | Zn | + | + |
| | Fe | + | + |
| | Mn | + | + |
| | Cd | + | + |
| | Pb | + | + |
| | As | - | - |
| | Ni | + | + |
| | Ba | + | + |
| | Cr | - | - |
| | Co | - | - |
| | Hg | + | + |

Environmental Concentration with The Predicted No Effect Concentration PEC/PNEC and Measured Environmental Concentration with the Predicted No Effect Concentration MEC/PNEC are generally used to assess the risk of these substances [20]. PNEC takes in consideration the sensitive organisms. MEC shows the concentration in environment. And PEC present the concentration emitted taking in consideration the dilution. The micropollutant is considered harmful when the quotient PEC/PNEC is above one (PEC/PNEC > 1) [21–23]. In this approaches, molecules are studied one by one. The fact that we cannot estimate the overall risk limits this approach [1,24–26].

Another way to assess the effect of micropollutants on humans and the aquatic environment is the life cycle analysis (LCA) of a molecule or group of molecules as it was highlighted in several works [27–29]. The LCA model focuses primarily on assessing the environmental impacts of substances throughout their life cycle, which includes their production, use and disposal. While LCA can provide valuable insights into the wider environmental consequences of substances, it is not specifically designed to analyze their effects on the human body or the aquatic environment in terms of health or toxicity. To assess the effects on human health or the aquatic environment, more specialized models or methods are generally used, such as risk assessment or toxicological studies. However, LCA is better suited to assessing the overall sustainability and environmental footprint of products, processes or services. Muñoz et al. discovered that 15 out of 98 micropollutants had a high risk on Humans and aquatic environment. While, based on USEtox® characterization factors [30] assessed the ecotoxicological impact of micropollutants in Spain.

Our study focused on assessing the impact of 46 organic and inorganic micropollutants belonging to 3 major families (Polycyclic Aromatic Hydrocarbons (PAHs), Polychlorinated biphenyls (PCBs), and Heavy Metals) quantified from the outlet and inlet of the Al-Hoceima city WWTP on Humans and Aquatic environment using LCA model.

## 2. Materials and methods

### 2.1. Targeted micropollutants

Samples were analyzed in 2022. 33 targeted molecules were found in wastewater. While 13 were quantified occasionally. These compounds, includes 03 heavy metals, 08 PCBs, and 02 PAHs (Table 1).

### 2.2. Sampling and analysis

The wastewater treatment plant of Al-Hoceima city operates on an activated sludge at low load [31]. It treats a daily flow of 9600 $m^3$ of wastewater from anthropogenic activities [31,32]. The system is composed of different treatment steps. Classically, the treatment is divided into: pre-treatment, secondary or biological treatment, tertiary treatment and sludge treatment [33,34]. Overall, three sets of samples were successfully collected. Composite samples were taken continuously at each site, using refrigerated automatic samplers maintained at 4°C. To prevent any risk of contamination of the samples and adsorption of pollutants during the collection process, these samplers were equipped with glass bottles and Teflon® pipes. In addition and in order to preserve the original distribution of pollutants between dissolved phases and suspended particles, samples were filtered as soon as possible through a 0.45 µm filter to remove fine particles. After filtration, the dissolved fraction was analysed within 24 hours of collection, while the particulate fraction was analysed within 48 hours [31,34–37]. The levels of PAHs and PCBs in the samples that were gathered were assessed using Gas Chromatography-Mass Spectrometry (GC-MS), while the concentrations of heavy metals (HMs) were determined through Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) [32].

### 2.3. Potential impact assessment of wastewater

This work aims, to evaluate the impact of wastewater discharged into sea, as the case in our study, on the aquatic environment and human health using a methodology. USEtox 2.12® was used to calculate the characterization factors (CF) for micropollutants with this equation: **CF = XF x EF x FF**.

with XF: ecotoxicity exposure factor / EF: the effect factor / FF: the fate factor.

USEtox is a scientifically sound consensus model that has been officially endorsed by the United Nations Environment Program (UNEP) Life Cycle Initiative. Its main objective is to provide a systematic and comprehensive approach to characterizing the potential human and ecotoxicological impacts of various chemicals used in different industrial processes and products. The cornerstone of the USEtox framework is its vast database, rich in characterization factors. These factors encompass a wide range of essential parameters, including those relating to the fate, exposure and effects of chemicals. By integrating and analyzing this wealth of data, USEtox enables a more accurate and comprehensive assessment of the potential environmental and health risks associated with chemical substances, making it a valuable tool for informed decision-making, sustainable product development and risk management in a variety of sectors.

Characterization factors for humans added the ingestion fraction (IF), which is the value token of MPs from water, air, and food (IF = XF x

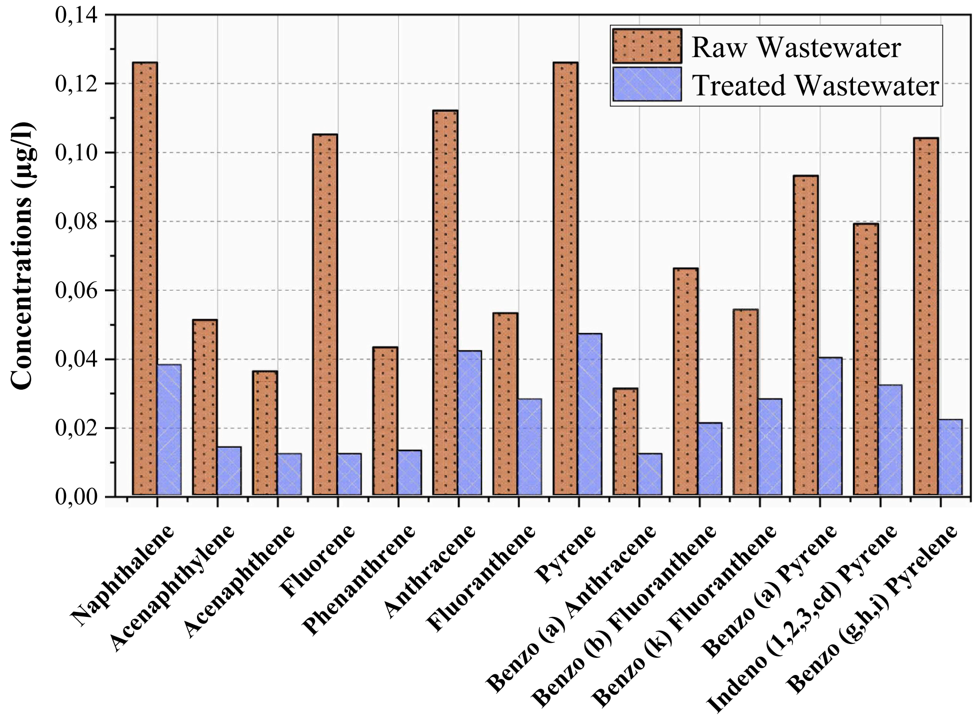


**Fig. 1.** Concentrations of PAHs in the inlet and outlet of the WWTP.

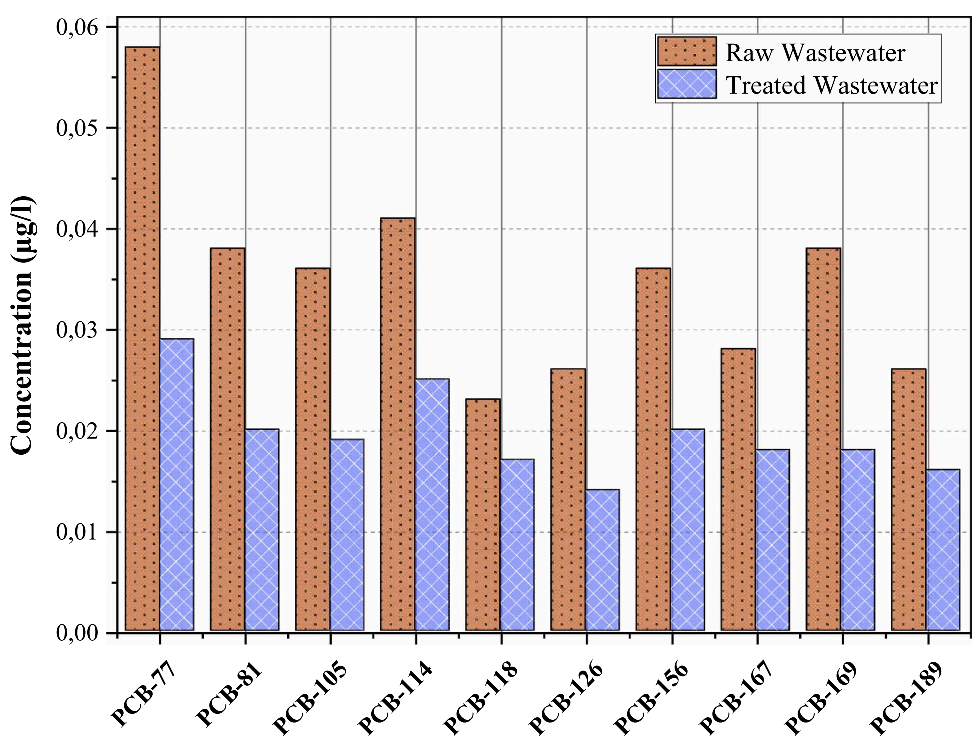


**Fig. 2.** Concentrations of PCBs in the inlet and outlet of the WWTP.

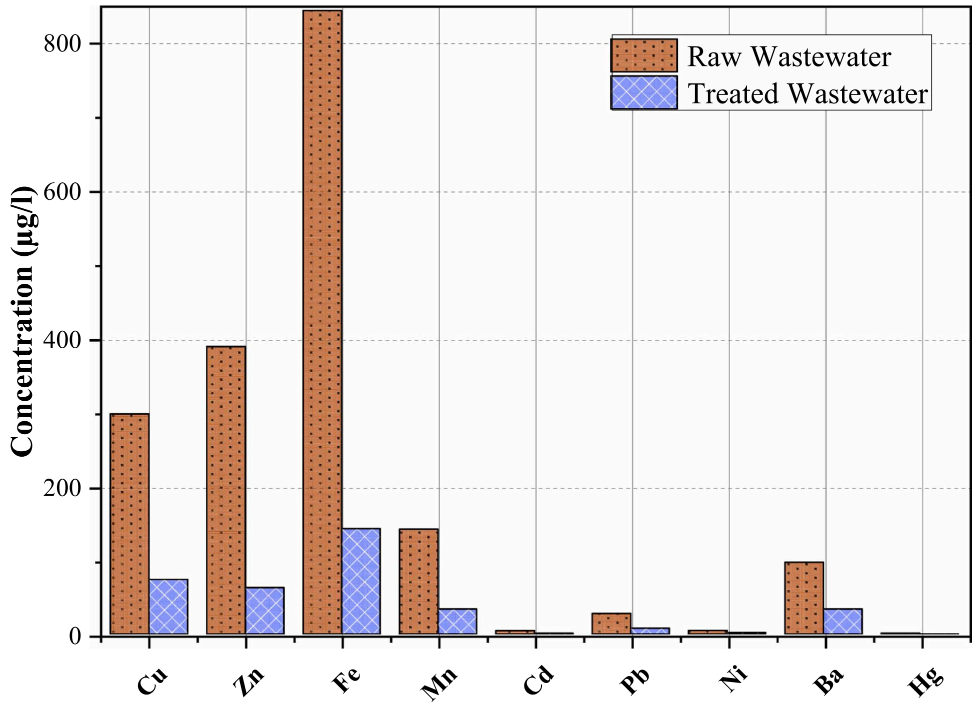


**Fig. 3.** Concentrations of HMs in the inlet and outlet of the WWTP.

FF). In this study, we project to assess the impact of each substance as well as the impact of the entire mixture of MPs. Then the potential impacts were calculated using this equation: **Impact potential** $= \sum$ **Characterization factor x Emitted Mass**. The emitted mass was obtained by multiplying the concentrations with the annual volume.

Disability Adjusted Life Years (DALYs) was used to determine the impact on human health. Potentially Disappeared Fraction integrated (PDF.m$^3$.d) was used to express the impact on the aquatic environment. In order to obtain the total score, we summed all the impacts.

### 2.4. Quantity of wastewater released in a year

To estimate the quantity of wastewater released into the aquatic environment, we considered that the volume entering and leaving the WWTP is stable. The WWTP receives a flow of 9600 m$^3$ daily. After multiplying it by 365 days, we got an estimated annual volume of 3504,000 m$^3$.

## 3. Results and discussion

### 3.1. Micropollutants concentrations

46 micropollutants (organic and inorganic) were studied, including 12 HMs, 18 PCBs and 16 PAHs. 71.74 % of organic and inorganic micropollutants searched were detected in raw and treated wastewaters (33/46). 13/46 of the rest were quantified occasionally in the three campaigns.

Concentrations in raw wastewater were 0.02–850 µg/L. The highest concentrations, logically, belong to heavy metals with 1.2–845 µg/L. Then, it comes PAHs with high molecular weight (0.09–1 µg/L). At the end, there are the PCBs and rest of PAHs with concentrations ranging between 0.01 and 0.09 µg/L.

The same compounds belonging to same families were detected in the outlet of the WWTP. Concentrations quantified were presented in Figs. 1–3. They ranged between 0.012 and 143 µg/L. Removals efficiencies were the highest for some inorganic micropollutants (more than 80 %), while they ranged between 50 % and 80 % for the rest of the compounds.

### 3.2. Assessing impact of MPs on Human health

The characterization factors along the Emitted masses from the WWTP obtained are presented in Table 2. A high concentration reflects high emitted masses into environment. The potential impact on Human health was assessed for 60 % of micropollutants (28/46), because of the lack of the concentrations or/and characterization factors. Characterization factor was equal to 0 for Chrysene, PCB-28, PCB-55, PCB-101, PCB-105, PCB-118, PCB-123, PCB-138, PCB-153, PCB-156, PCB-157, PCB-167, PCB-169, PCB-180, PCB-189, Fe, Mg and Co.

Observable effects (e.g., in vivo and in vitro bioassays) have demonstrated that chemicals pose a risk to human health. PCBs, PAHs, and HMs represent one such case.

In this investigation, results obtained for impact assessment ranged between 10 and 3 and 10–9. The total impact score was 10–2 (Fig. 4). The highest impact score belonged to inorganic micropollutants (Ba, Hg, Zn and Cd). These elements represented 92 % of the total impact on Human health score. When deciding on priorities, it is important to consider the toxicity of the elements, not just the mass released. The results of this study prove that the emission of MPs into seawater may affect the Human health directly or indirectly [38]. 3/10 main contributors were PAHs produced by human activities. The compounds with the highest score are considered to be carcinogenic [38].

Micropollutants, whether organic or inorganic in origin, have significant effects on human health. Heavy metals, such as lead and mercury, and volatile organic compounds (VOCs) can cause respiratory problems, such as lung irritation and infections. Some organic micropollutants, such as pesticides and pharmaceuticals, can cause liver and kidney toxicity, affecting metabolic health. In addition, endocrine disruptors among organic micropollutants can disrupt the hormonal system, leading to reproductive problems, developmental abnormalities and diseases such as cancer. Some micropollutants, notably polycyclic aromatic hydrocarbons (PAHs) and organochlorine compounds, are classified as carcinogenic to humans, increasing the risk of cancer [39–42]. Heavy metals, such as lead and mercury, can also have harmful effects on the nervous system, leading to neurological and cognitive disorders. Finally, ingesting micropollutants through contaminated water or marine products can cause gastrointestinal problems. It is

**Table 2**
Human health characterization factor [DALY/kg emitted].

| Substance Name | Estimated annual volume (m3) | Emitted Mass in kg | Human health characterization factor [DALY/kg emitted] | | |
|---|---|---|---|---|---|
| | | | cancer | non-canc | total |
| Naphthalene | 3504000 | 0.133152 | 3.8815E−08 | 2.4292E−09 | 4.1244E−08 |
| Acenaphthylene | 3504000 | 0.049056 | 2.6216E−06 | n/a | 2.6216E−06 |
| Acenaphthene | 3504000 | 0.042048 | 2.7205E−06 | 2.2595E−08 | 2.7431E−06 |
| Fluorene | 3504000 | 0.042048 | 2.4544E−06 | 2.8539E−08 | 2.483E−06 |
| Phenanthrene | 3504000 | 0.045552 | 1.3969E−05 | n/a | 1.3969E−05 |
| Anthracene | 3504000 | 0.147168 | 0.00018 | 2.6163E−08 | 0.00018003 |
| Fluoranthene | 3504000 | 0.098112 | 5.1867E−05 | 6.0309E−07 | 5.247E−05 |
| Pyrene | 3504000 | 0.164688 | 3.071E−05 | 5.9514E−07 | 3.1305E−05 |
| Benzo (a) Anthracene | 3504000 | 0.042048 | 0.00039097 | n/a | 0.00039097 |
| Chrysene | 3504000 | n/a | n/a | n/a | n/a |
| Benzo (b) Fluoranthene | 3504000 | 0.073584 | 0.00265367 | n/a | 0.00265367 |
| Benzo (k) Fluoranthene | 3504000 | 0.098112 | 0.00110217 | n/a | 0.00110217 |
| Benzo (a) Pyrene | 3504000 | 0.14016 | 0.00291188 | n/a | 0.00291188 |
| Indeno (1.2.3.cd) Pyrene | 3504000 | 0.112128 | 0.00109856 | n/a | 0.00109856 |
| Dibenzo (a.h) Anthracene | 3504000 | n/a | 0.02549973 | n/a | 0.02549973 |
| Benzo (g.h.i) Pyrelene | 3504000 | 0.077088 | 2.0546E−05 | n/a | 2.0546E−05 |
| PCB−28 | 3504000 | n/a | n/a | n/a | n/a |
| PCB−52 | 3504000 | n/a | n/a | n/a | n/a |
| PCB−77 | 3504000 | 0.101616 | n/a | 0.00109856 | 0.00109856 |
| PCB−81 | 3504000 | 0.0681 | n/a | 3.1305E−05 | 3.1305E−05 |
| PCB−101 | 3504000 | n/a | n/a | n/a | n/a |
| PCB−105 | 3504000 | 0.066576 | n/a | n/a | n/a |
| PCB−114 | 3504000 | 0.0876 | 5.247E−05 | n/a | 5.247E−05 |
| PCB−118 | 3504000 | 0.059568 | n/a | n/a | n/a |
| PCB−123 | 3504000 | n/a | n/a | n/a | n/a |
| PCB−126 | 3504000 | 0.049056 | n/a | 0.00291188 | 0.00291188 |
| PCB−138 | 3504000 | n/a | n/a | n/a | n/a |
| PCB−153 | 3504000 | n/a | n/a | n/a | n/a |
| PCB−156 | 3504000 | 0.07008 | n/a | n/a | n/a |
| PCB−157 | 3504000 | n/a | n/a | n/a | n/a |
| PCB−167 | 3504000 | 0.063072 | n/a | n/a | n/a |
| PCB−169 | 3504000 | 0.063072 | n/a | n/a | n/a |
| PCB−180 | 3504000 | n/a | n/a | n/a | n/a |
| PCB−189 | 3504000 | 0.056064 | n/a | n/a | n/a |
| Cu | 3504000 | 259.296 | n/a | 1.531E−08 | 1.531E−08 |
| Zn | 3504000 | 220.752 | n/a | 2.5792E−05 | 2.5792E−05 |
| Fe | 3504000 | 501.072 | n/a | n/a | n/a |
| Mg | 3504000 | 119.136 | n/a | n/a | n/a |
| Cd | 3504000 | 4.5552 | 6.1146E−06 | 0.00038516 | 0.00039128 |
| Pb | 3504000 | 28.032 | 9.6434E−08 | 7.9424E−06 | 8.0389E−06 |
| As | 3504000 | n/a | 0.00013398 | 0.00233006 | 0.00246404 |
| Ni | 3504000 | 7.008 | 3.6625E−05 | 4.8389E−07 | 3.7109E−05 |
| Ba | 3504000 | 119.136 | n/a | 6.5156E−05 | 6.5156E−05 |
| Cr | 3504000 | n/a | n/a | 4.0766E−12 | 4.0766E−12 |
| Co | 3504000 | n/a | n/a | n/a | n/a |
| Hg | 3504000 | 0.7008 | 0.00033553 | 0.00932517 | 0.00966071 |

n/a: Not applicable

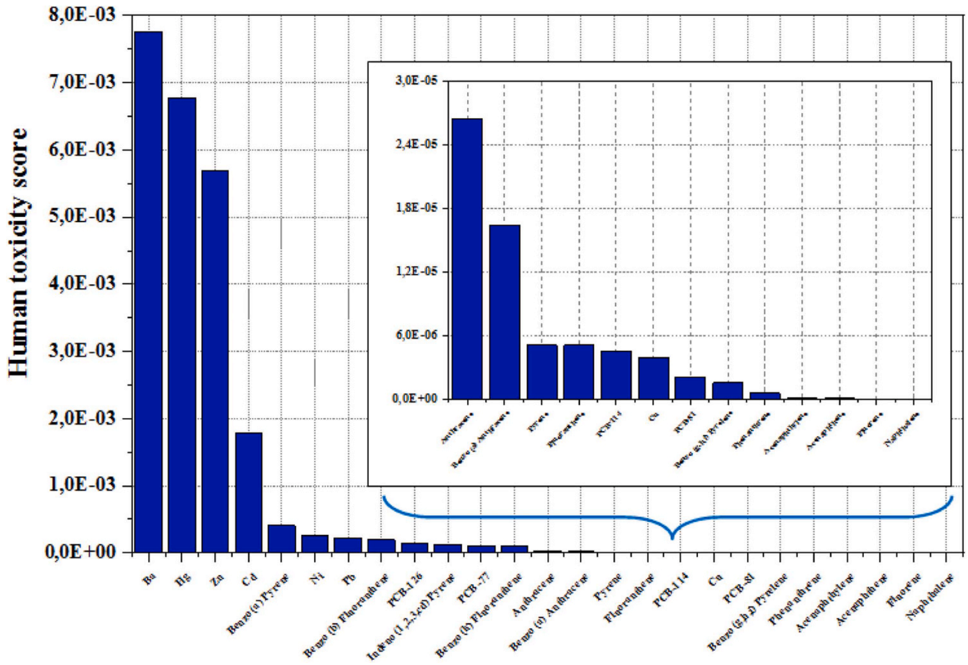


**Fig. 4.** Human toxicity impact score.

crucial to reduce exposure to micropollutants and implement preventive measures to minimise the risks to human health associated with these substances.

Aemig et al. assessed the impact on Human health of 286 organic and inorganic micropollutants emitted by WWTPs in France. The impact was estimated for 109/286 mentioning the lack of data on toxicity or concentrations. As, Zn, some PAHs and pesticides had the highest score. While, Muñoz et al. [23] studied the impact of 98 micropollutants. They considered a situation in which treated wastewater was used for agricultural irrigation (discharged into the soil). The characterization factor was calculated using two methods (EDIP97 and USES-LCA). Four substances (two for each method), respectively, had the highest impact: gemfibrozil, nicotine, 2,3,7,8-TCDD and hexachlorobenzene. In our study, these micropollutants were not considered [43].

### 3.3. Assessing impact of MPs on aquatic environment

Ecotoxicity characterization factors (Ecotox. Charact. Factors) were found for over 76 % of micropollutants in this study (Table 3). For the total organic and inorganic micropollutants, the impact was estimated for 35 compounds. Five key contributors among PAHs and PCBs include Pyrene, Anthracene, Benzo(a)Anthracene, Fluoranthene and PCB-77 with and impact going from 3.43E+02–1.21E+01 PDF.m$^3$.d (Fig. 5). With a value of 3.43E+02, Pyrene had the highest impact contributing by 73 % alone. While Anthracene, Benzo(a)Anthracene, Fluoranthene, and PCB-77 had a respective percentage of 13,5,3 and 2 %. Inorganic micropollutants had the lowest impact ranging from 1.45E-11–6.34E-19 PDF.m$^3$.d. Even if the inorganic micropollutants are present in Aquatic environment, but it is difficult to identify their impact since the Characterization factors afforded by USEtox 2.12® should be interpreted carefully.

Impact on Aquatic environment of 45 and 88 PPCPs was assessed respectively by [30,43]. Total impact of the same order of importance was observed. At low concentrations, micropollutants can have a considerable impact on the aquatic environment, in contrast to the risk to human health. Mainly, the difference of impact is due to emitted masses. To identify impacts of micropollutants, [23] used Life Cycle Assessment. Two models were used USES-LCA and EDIP97. The substances with highest impact, respectively, are fluoxetine and ibuprofen. In other study, they paired in vitro impacts of MPs and biotests. The results showed high impact for some substances agreeing with our study [44].

Researchers worked on the impact of changing wastewater treatment process on biodiversity [45]. After adding a tertiary treatment (activated carbon filtration), they noticed no impact on the aquatic environment. This is due to the improvement of oxygen concentrations. However, the substances present in the effluent were negligible.

Other works, such as [25] and [26], confirmed occurrence of organic MPs in aquatic organisms, demonstrating bioaccumulative effect of these substances in aquatic food chains. In each fish, a number of eleven micropollutants were detected, which increases the risk to other fish and especially to humans [46,47].

Micropollutants, whether organic or inorganic, have substantial effects on the aquatic environment. They can have a series of worrying consequences, including accumulation in ecosystems, disruption of food chains and reduced biodiversity. Organic micropollutants, such as pesticides and pharmaceuticals, can contaminate rivers and oceans, directly affecting the aquatic organism's life. This contamination can disrupt reproductive cycles, cause genetic mutations and have harmful impacts on aquatic flora and fauna. In addition, inorganic micropollutants, such as heavy metals, can accumulate in river sediments, affecting the quality of aquatic habitats. The effects spread through food chains, affecting fish and other marine species, and ultimately humans consuming seafood. Reduced biodiversity, altered aquatic ecosystems and reduced water quality are major concerns linked to the presence of micropollutants in aquatic environments.

## 4. Conclusions

This research has been conducted on the impact of the MPs on human health and the aquatic environment. The total score for the impact on human health is 10–2, generally varying between 10 and 3 and 10–9. The inorganic micropollutants (Ba, Hg, Zn and Cd) had the highest score with a percentage of 92 % of the total score. The total impact of micropollutants on the aquatic environment was estimated for 25 compounds. Five key contributors: Pyrene, Anthracene, Benzo(a) Anthracene, Fluoranthene and PCB-77 with an impact ranging from 3.43E+02–1.21E+01 PDF.m$^3$.d. with a value of 3.43E+02, Pyrene had

**Table 3**
Aquatic Environment Characterization factor [PDF.$m^3$.day.$kg^{-1}$].

| Substance Name | Mean concentration in the outlet (μg/L) | Estimated annual volume (m3) | Emitted Mass in kg | Ecotox. Charact. factor [PDF.m3.day.kg-1] |
|---|---|---|---|---|
| Naphthalene | 0.038 | 3504000 | 0.133152 | 0.00813289 |
| Acenaphthylene | 0.014 | 3504000 | 0.049056 | n/a |
| Acenaphthene | 0.012 | 3504000 | 0.042048 | 0.83122894 |
| Fluorene | 0.012 | 3504000 | 0.042048 | 3.87967028 |
| Phenanthrene | 0.013 | 3504000 | 0.045552 | 20.5255943 |
| Anthracene | 0.042 | 3504000 | 0.147168 | 430.785283 |
| Fluoranthene | 0.028 | 3504000 | 0.098112 | 158.923509 |
| Pyrene | 0.047 | 3504000 | 0.164688 | 2084.48231 |
| Benzo (a) Anthracene | 0.012 | 3504000 | 0.042048 | 573.991056 |
| Chrysene | n/a | 3504000 | n/a | n/a |
| Benzo (b) Fluoranthene | 0.021 | 3504000 | 0.073584 | n/a |
| Benzo (k) Fluoranthene | 0.028 | 3504000 | 0.098112 | n/a |
| Benzo (a) Pyrene | 0.04 | 3504000 | 0.14016 | 0.74132405 |
| Indeno (1.2.3.cd) Pyrene | 0.032 | 3504000 | 0.112128 | n/a |
| Dibenzo (a.h) Anthracene | n/a | 3504000 | n/a | 0.14803029 |
| Benzo (g.h.i) Pyrelene | 0.022 | 3504000 | 0.077088 | n/a |
| PCB−28 | n/a | 3504000 | n/a | 1.31444044 |
| PCB−52 | n/a | 3504000 | n/a | 4.01323712 |
| PCB−77 | 0.029 | 3504000 | 0.101616 | 119.2009 |
| PCB−81 | 0.020 | 3504000 | 0.0681 | 1.31444044 |
| PCB−101 | n/a | 3504000 | n/a | 893.593531 |
| PCB−105 | 0.019 | 3504000 | 0.066576 | 2.16128625 |
| PCB−114 | 0.025 | 3504000 | 0.0876 | 43.5183401 |
| PCB−118 | 0.017 | 3504000 | 0.059568 | 6.39610779 |
| PCB−123 | n/a | 3504000 | n/a | 25.6873149 |
| PCB−126 | 0.014 | 3504000 | 0.049056 | 76.1204561 |
| PCB−138 | n/a | 3504000 | n/a | 414.231911 |
| PCB−153 | n/a | 3504000 | n/a | 49.7798592 |
| PCB−156 | 0.020 | 3504000 | 0.07008 | n/a |
| PCB−157 | n/a | 3504000 | n/a | n/a |
| PCB−167 | 0.018 | 3504000 | 0.063072 | n/a |
| PCB−169 | 0.018 | 3504000 | 0.063072 | 0.0552413 |
| PCB−180 | n/a | 3504000 | n/a | n/a |
| PCB−189 | 0.016 | 3504000 | 0.056064 | n/a |
| Cu | 74 | 3504000 | 259.296 | 1.8088E−16 |
| Zn | 63 | 3504000 | 220.752 | 6.8798E−15 |
| Fe | 143 | 3504000 | 501.072 | 2.8965E−14 |
| Mg | 34 | 3504000 | 119.136 | 2.5771E−15 |
| Cd | 1.3 | 3504000 | 4.5552 | 1.3928E−19 |
| Pb | 8 | 3504000 | 28.032 | 2.7356E−17 |
| As | n/a | 3504000 | n/a | 6.0432E−16 |
| Ni | 2 | 3504000 | 7.008 | 8.3624E−17 |
| Ba | 34 | 3504000 | 119.136 | 2.3696E−16 |
| Cr | n/a | 3504000 | n/a | 3.5004E−19 |
| Co | n/a | 3504000 | n/a | 3.6444E−15 |
| Hg | 0.2 | 3504000 | 0.7008 | 1.0164E−18 |

the highest impact, contributing 73 % by itself.

The lack of data on the impact of micropollutants on human health and the aquatic environment is notable. The calculation of the impact score was calculated by a limited number of molecules due to the lack of concentrations or characterization factors.

The discharge of organic matter into aquatic ecosystems can result in eutrophication, oxygen depletion, and habitat disruption, negatively impacting aquatic biodiversity. Additionally, heavy metals, although initially present in water in small quantities, can bioaccumulate and biomagnify in the food chain, leading to human exposure and potential health risks when consuming contaminated fish and seafood. Effective management strategies are crucial to mitigate these impacts and safeguard both aquatic biodiversity and human health.

This study raised the issue of the presence of micropollutants in the environment, and the need to prohibit or reduce at source. Finishing treatments have proven to be effective against micropollutants, but they do not manage to eliminate them completely.

## CRediT authorship contribution statement

**Chaimae Haboubi:** Visualization, Validation. **Hatim Faiz:** Methodology, Formal analysis, Data curation. **Aouatif El Abdouni:** Methodology, Investigation. **Fouad Dimane:** Writing – review & editing, Visualization, Supervision. **Kawthar El Ahmadi:** Methodology, Resources. **Imane Dira:** Data curation, Investigation. **Yahya El hammoudani:** Writing – original draft, Data curation, Conceptualization. **Abdelaziz TOUZANI:** Methodology, Software. **Khadija Haboubi:** Writing – original draft, Software, Investigation. **Mohamed MOUDOU:** Software, Visualization. **Abdelhak Bourjila:** Writing – original draft, Software, Methodology. **Mustapha EL BOUDAMMOUSSI:** Investigation, Methodology. **Iliass Achoukhi:** Visualization, Validation, Software. **Maryam ESSKIFATI:** Investigation, Methodology. **Chaimae Benaissa:** Software, Methodology, Formal analysis.

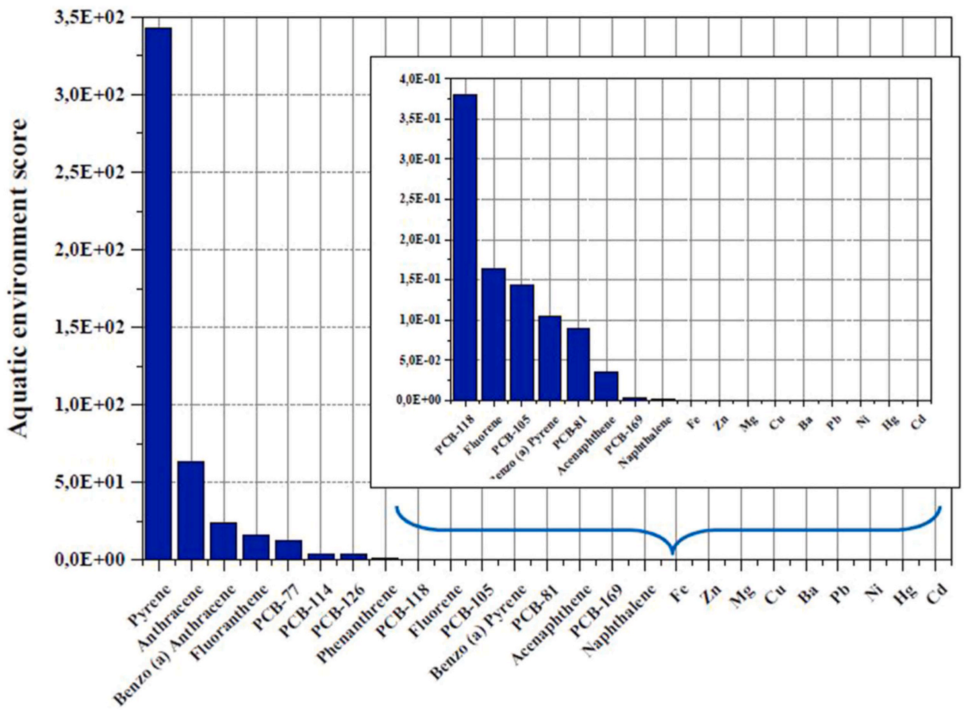


**Fig. 5.** Ecotoxicity impact score.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Data will be made available on request.

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