

Occurrence and Distribution of Per- and Polyfluoroalkyl Substances from Multi-

Industry Sources to Water, Sediments and Plants along Nairobi River Basin, Kenya

Flora Chirikona^{1*}, Natalia Quinete², Jesleen Gonzalez², Gershom Mutua¹, Selly Kimosop¹, Francis Orata¹

¹Department of Pure and Applied Chemistry, Masinde Muliro University of Science and Technology. P.O Box 190 Kakamega 50100

²Department of Chemistry & Biochemistry Institute of Environment, Freshwater Resources Division Florida International University, 3000 NE 151st street, Biscayne Bay Campus North Miami, FL33181, USA

Abstract:

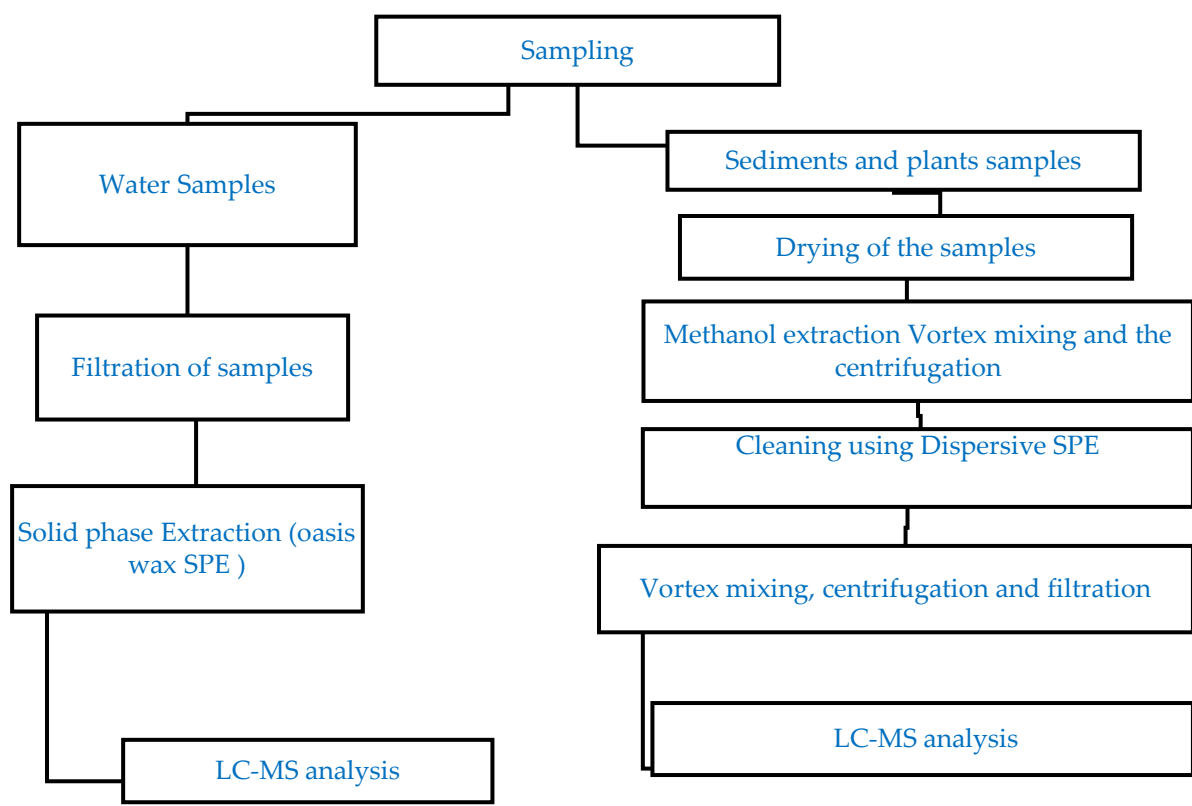
Per- and polyfluoroalkyl substances (PFAS) are ever-present pollutants in the environment. They are persistent and bio-accumulative with deleterious health effects on biota. This study assesses the levels of PFAS in environmental matrices along the Nairobi River, Kenya. An aggregate of 30 PFAS were determined in water, while 28 PFAS were detected in sediments and plants using solid phase extraction then liquid chromatography–mass spectrometric techniques. In water, higher levels of perfluoroundecanoic acids of up to 39.2 ng L⁻¹ were observed. Sediment and plant samples obtained in the midstream and downstream contained higher levels of perfluorooctanoic acid of up to 39.62 and 29.33 ng g⁻¹, respectively. Comparably, levels of long-chain PFAS were higher in water and sediments than in plants. Sediment/water log distribution of selected PFAS ranged between 2.5 (perfluoroundecanoic acid) and 4.9 (perfluorooctane sulfonate). The level of perfluorooctane sulfonate (1.83 ng L⁻¹) in water is above the acceptable level in surface water posing high human health and ecological risks. The observed PFAS concentrations and distribution were attributed mainly to multi-industries located along the river, among other sources. The knowledge of PFAS occurrence and distribution in Nairobi River, Kenya, provides important information to local regulatory agencies for PFAS pollution control.

Introduction

- Per- and polyfluoroalkyl substances (PFAS) are emerging man-made pollutants of great environmental concern.
- They are persistent, bio-accumulative, and toxic [1].
- Some of the adverse health effects associated with exposure to PFAS include reduced kidney functioning, adverse pregnancy outcomes, thyroid disruption, and metabolic syndrome [2].
- Some PFAS, such as perfluorooctane sulfonate (PFOS) as well as perfluorooctane sulfonyl fluoride (PFOSF) and related precursors, were added in May 2009 as the first fluorinated persistent organic pollutants (POPs) in the Stockholm Convention POPs list [4].
- There is limited information on the environmental distribution and emission of PFAS in Africa [10].
- National Implementation Plan (NIP) of Kenya (2014), recommended that the levels of PFAS in different environmental matrices should be determined.
- There is a lot of literature on pollution of Nairobi River by different contaminants. However, none of these studies have reported on the levels of PFAS. We therefore focus on assessing the occurrence and distribution of PFAS in surface water, sediments, and plants from Nairobi River, Kenya. The water/sediments log distribution coefficient of selected PFAS along Nairobi River matrices was also determined

Materials and methods

- Samples were collected in eight regions along Nairobi River in areas where detection of PFAS was most expected due to anthropogenic input.
- Water samples were concentrated using SPE cartridge, plants and sediments samples were extracted using methanol concentrated using dispersive SPE and analysis was done using LC-MS



Results and discussion

- A total of 30 PFAS were found in Nairobi River water, while 28 PFAS congeners were detected in sediments and plants. The total PFAS concentration in a location sampling site was determined by the summation of the concentration of all PFAS congeners in the same location. Figure 2 shows the spatial distribution of PFAS in the Nairobi River water.

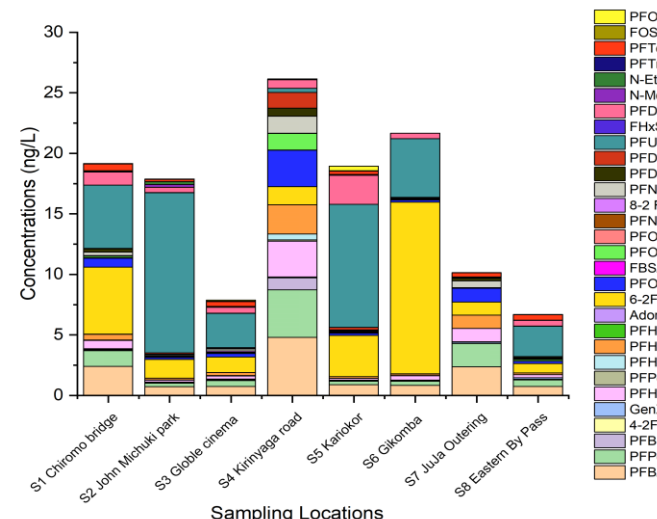


Figure 1. PFAS spatial distribution in Nairobi River water.

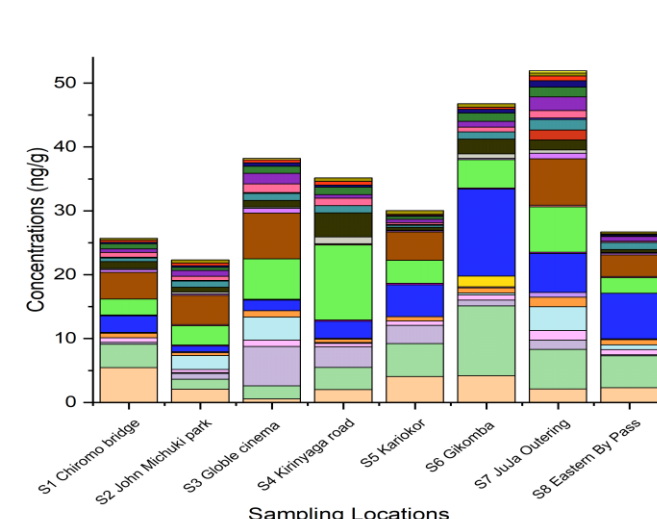


Figure 3. PFAS spatial distribution in sediments from the Nairobi River Basin.

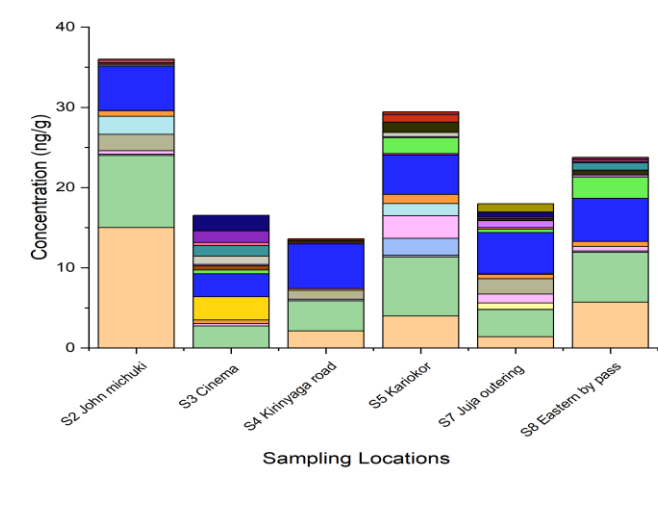
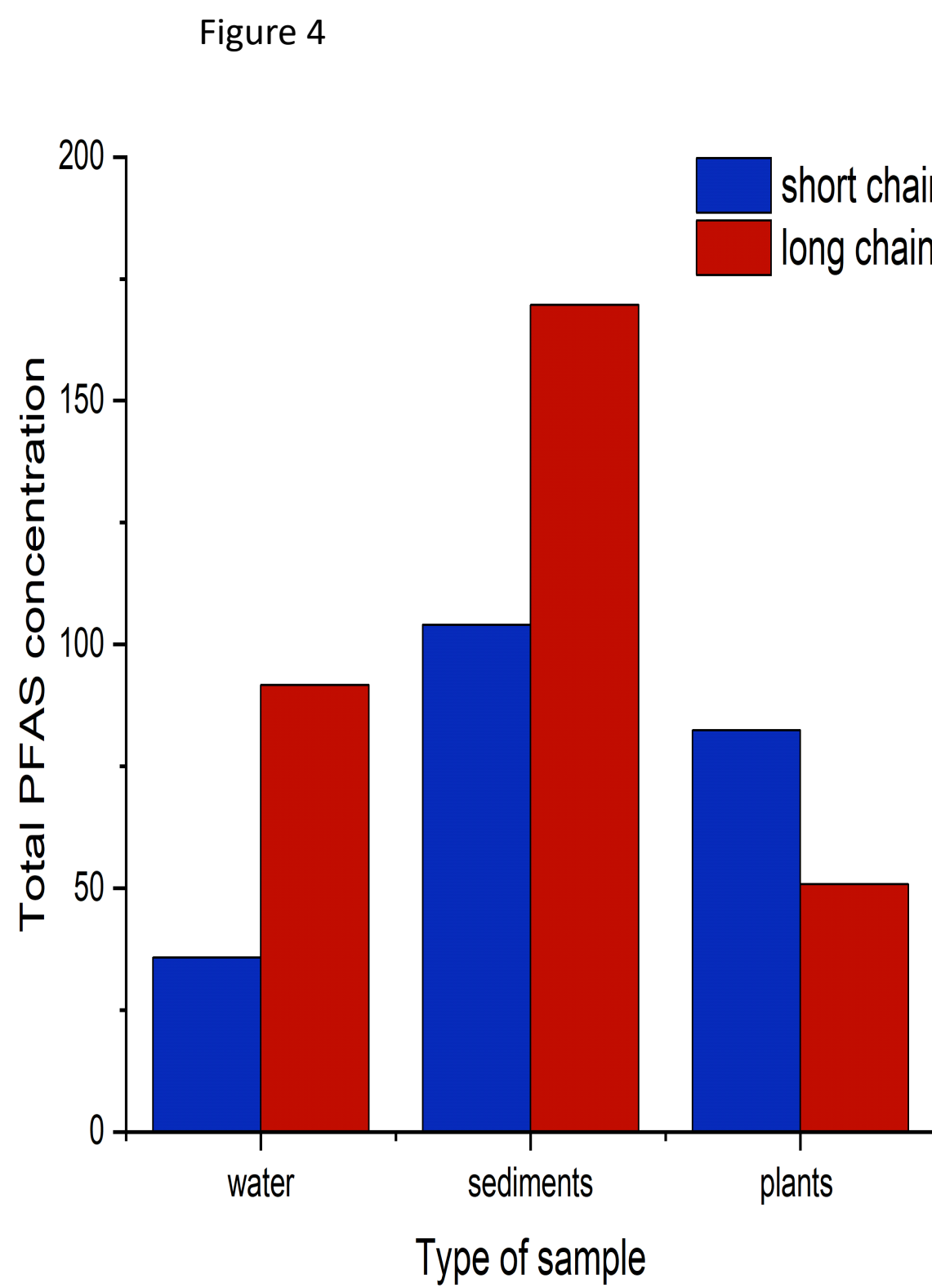
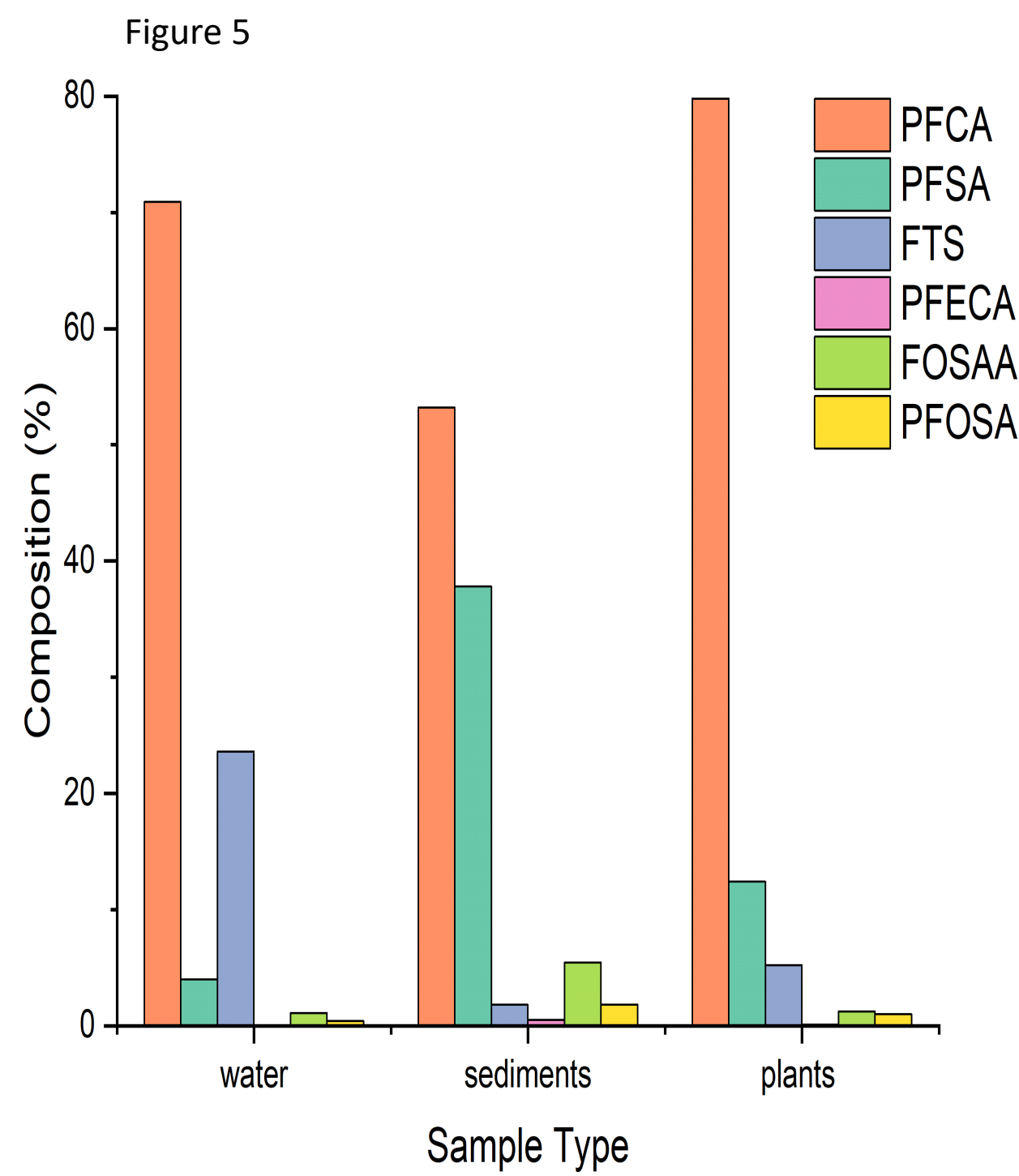


Figure 3. PFAS spatial distribution in sediments from the Nairobi River

- In water, higher concentrations of PFAS were observed in sampling points found upper stream and midstream, this sampling point are located near numerous cottage industries such as paints, panel beating, car repair/garage, dyeing industries, and food vending industries.
- Industrial discharge is known to contribute heavily to the spread of PFAS in surface water [8].
- The level of PFAS in sediments from the Nairobi River Basin is higher compared to their corresponding PFAS in water.
- PFAS can strongly bind to organic matter in sediments via hydrophobic interactions, which makes sediments an important sink and reservoir of PFAS [19,20].
- Plant samples were collected in only six sites: S2, S3, S4, S5, S7, and S8. The PFAS levels obtained in plant samples were slightly lower (about 1.5 times lower) than in sediments. The primary pathway for translocation of PFAS from the environment to plants is through the roots.
- When PFAS are categorized according to chain length, perfluoroalkyl substances with C4–C7 are regarded as short chain while those with C8 and above are regarded as long-chain PFAS [20].
- The sum of long-chain PFAS in the water and sediments was higher than short chain. In plants, short chain PFAS were predominant as shown in figure 4
- PFAS can be classified as follows: perfluoroalkyl carboxylic acids (PFCA), perfluoroalkyl sulfonic acid (PFSA), perfluoroalkane sulfonamide (PFOSA), perfluoroalkane sulfonamido acetic acid (FOSAA), fluorotelomer sulfonic acid (FTS), and perfluoroether carboxylic acid (PFECA).

- When categorized in classes, by adding the concentration of all compounds of the same category and determining their percentage composition, the composition varied in the different sample types as shown in Figure 5.

- The sum of PFCA and PFSA represents 70–90% of the total PFAS detected in river water, sediments, and plants.



Distribution coefficient

Most compounds had a mean distribution coefficient value above 1 as shown in the table below. The mean log Kd values ranged between 2.5 (PFuDA) and 4.9 (PFOS). The log Kd values of PFSA were higher than the log Kd values of PFCA; for instance, PFOS had the highest average log Kd value of 4.8 followed by PFBS (4.4) while PFOA had a mean log Kd value of 3.9 and PFBA had a log Kd value of 3.2. This shows that the sorption of sulfonates is stronger than the analogue carboxylic acids [43]. The high log Kd values obtained here indicate that sediments act as a reservoir of PFAS and hence a major PFAS source in the food web.

Table. The distribution coefficient values of selected PFAS in water and sediments

Sampling Site	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUDA	PFDoA	PFTeDA
S1	3.4	3.5	3	3.2	3.5	2.7	3.6	2	2.8	2.8
S2	3.5	3.7	3.4	3.5	3.8	3.6	4	1.8	3.2	3.4
S3	2.9	3.6	3.6	3.6	3.8	3.1	4.1	2.6	3.4	3.1
S4	2.6	2.9	2.3	2.4	3	3.9	3.7	3.4	3.2	-
S5	3.7	4.3	3.7	3.7	4.4	2.9	4	1.5	2.1	2.8
S6	3.7	4.5	3.4	3.8	4.9	4.1	4.7	1.4	3.2	-
S7	3	3.5	3.1	3.1	3.7	3	3.9	4.5	4.6	3.3
S8	3.5	4	3.5	3.7	4.6	3.3	3.7	2.6	2.6	2.4
Mean	3.3	3.8	3.3	3.4	4	3.1	4	2.5	3.2	3.3

Key: - Log Kd value not calculated. S1 to S8 as designated in Table

Conclusion

This study presents new knowledge on occurrence and distribution of PFAS in water, sediments, and plants in the Nairobi River basin. Perfluoroalkyl substances are widely distributed within the environmental matrices in the Nairobi River basin. The study offers an insight in the present state of PFAS pollution in the river, providing crucial information to the public and the government on the quality of water in respect to PFAS. The data presented can initiate the development of guide lines and management strategies

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