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Pesticide Residues in Untreated and Partially Treated Municipal Wastewater: Potential Risks of Surface Water Contamination via Outfalls

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Abstract: ***Municipal wastewater is a significant pathway for the transport of pesticide residues into aquatic environments, particularly in rapidly urbanizing and agriculturally intensive regions. This study investigates the occurrence and distribution of selected organochlorine pesticides in untreated and partially treated municipal wastewater discharging into the river Ganga through 28 major outfalls in West Bengal, India. Composite wastewater samples were collected and analyzed using gas chromatography–mass spectrometry (GC–MS) following standard extraction protocols. Sixteen target pesticides, including HCH isomers, DDTs, Endosulfans, Heptachlor, Aldrin, Dieldrin, and Endrin, were examined. The results revealed the widespread presence of pesticide residues across the study area, with Endosulfans being the most dominant group, followed by DDTs and Heptachlors. Concentrations of certain compounds, such as γ-HCH and Heptachlor, indicated ongoing usage despite regulatory restrictions, while the detection of degradation products suggested historical contamination. The study highlights that conventional wastewater treatment systems are not fully effective in removing these persistent organic pollutants, allowing their continuous discharge into the river system. The presence of such contaminants poses potential ecological and human health risks due to their toxicity, persistence, and bioaccumulative nature. This work provides important baseline data on pesticide contamination in municipal wastewater and emphasizes the need for improved treatment technologies, stricter regulatory enforcement, and sustainable management practices to mitigate pollution in the Ganga river basin.***

Keywords: Pesticides, Municipal Wastewater, GC-MS, Ganga River, Outfalls, Emerging Contaminants, Environmental Pollution

1. Introduction

Municipal wastewater discharge are among the primary sources of organic substances released to water environment. A systematic check on the presence and occurrence of pesticides in municipal wastewater disclosed that the concentration of these contaminants in wastewaters in South Asian region usually inclined to higher compare to those in European and North American countries (Tran et al., 2018). It is very common that these pesticides are physically, chemically structurally diversified. This affect the efficiency of sewage treatment plants to deal with their varying operational condition as well as their partial and full removal. As a result, many pesticide residues are still in higher concentration in treated or semi treated wastewater. From the study of previous literature the organic contaminants mainly found in municipality wastewater are generally wellness products and medicines, products use for personal care, preservatives, flame neutralizer, hormones, insecticides, pesticides, plasticizers and fertilizers (Qi et al., 2015; Loos et al., 2013). The conventional sewage treatment plants are not designed to remove these organic contaminants from wastewater that are discharging to surface water bodies. Although the previous literatures targeted a large number of organic contaminants, these investigations can still overlook some of the potentially harmful components (Petrie et al., 2015). Therefore a focused analytical assessment is required.

Concentration analysis of the organic contaminants in water needs modern technology like gas-chromatography or liquid chromatography analysis. But previous investigations of the presence of these contaminants in municipal wastewater based on the technologies are very few in numbers. For example, Huang et al (2020) applied GC/MS for determination of personal care products and drugs in treated or untreated municipal wastewaters in a tropical coastal city in china. Gros et al. (2017) carried out chemical screening of municipal wastewaters with the help of high-resolution mass spectrometry and discovered 79 organic contaminants including pesticides, personal products, medical drugs and fluoroalkyl compounds. In the last few decades municipality wastewater analysis using GC/MS approaches were also conducted (Eriksson et al., 2003; Wluka et al., 2017; Blum et al., 2017).

All the mentioned researches on municipal wastewater were executed in industrially developed countries like China, Europe or US. Recent decades are a significant acceleration of urbanization in newly industrialized nations as well as a shift in global industrial manufacturing. The composition of organic contaminants in municipal wastewaters and consequently in aquatic systems is significantly influenced by the consumption of industrially produced consumer goods in these economically rapidly expanding urban countries. But in research these are taken into consideration very rarely. India is an economically and industrially developing country with

a huge population volume. A very large percentage of these population are strongly dependent on crop productivity as their primary source of livelihood. Application of chemicals like pesticides, fertilizers, insecticides or herbicides are growing day by day to meet the demand of production quality and quantity. These chemical compounds are eventually getting mixed with the nearby surface water bodies through municipality outfalls along with wastewaters from other sources. These sources includes various large and small scale pesticide production industries, discharge from municipal areas using insect repellent etc. Chakrabarty et al (2016), Sah et al (2020), Duttagupta et al. (2020), Bhattyacharya et. al (2021), Rani et al (2021) reviewed the concentration status of harmful pesticides in Ganga river in India. But the municipality outfalls causing pesticide concentration in river by carrying wastewater from multiple sources are yet to be discovered and remain unconsidered so far.

In general the overall objective of this study was to identify targeted analytes more specifically pesticides and their concentration in municipal wastewater getting discharged into river Ganga. Twenty eight numbers of municipality drains were chosen to conduct this study. Quantity of waste water getting mixed into the river through these municipality drains are affecting the river water quality in several ways. Pesticide residues reaching river water can cause serious threats to the environment as well as can pressurize the conventional water treatment plants. The findings of the study can act as a reference of anticipated amount of pesticides present in municipal wastewater and also a baseline study of organic contaminants that can be expected in such wastewater. Sometimes targeted screening of compounds can overlook various important contaminants where as non-target screening could be a more holistic approach for the identification of wide variety of structurally diversified organic pollutants.

2. Methodology

2.1 Study Area and wastewater sample collection:

Municipality outfalls carry wastewater from different sources (industries, agricultural lands, residential areas etc.) and discharge directly into nearby surface water body. So there is always a possibility of different contaminants coming from respective sources getting mixed with river water. In West Bengal there are 56 numbers of municipality outfalls discharging into River Ganga, popularly known as Hughli River in Bengal. According to a report by Central Pollution Control Board (CPCB) the estimated approximate total of 6,628 MLD of wastewater get discharged into the Ganga in West Bengal through 56 municipal outfalls. The research area considered 28 numbers of outfalls among the total 56 numbers distributed in left and right bank of the river which approximately covers around 72.72 km of the river length (Fig-1). The outfalls are distributed over the area with dense population, industrial belt and agricultural lands including the capital city Kolkata (Table 1 and Table 2).

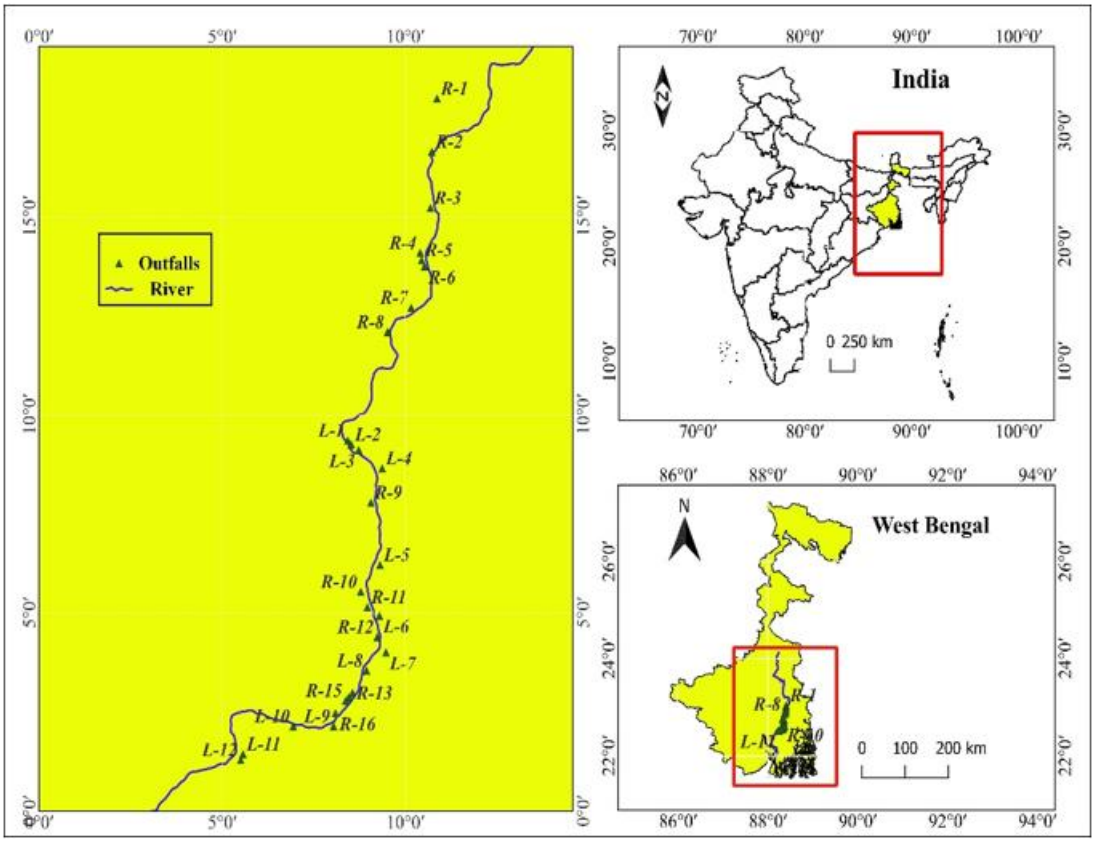


Figure 1: Location of wastewater water sampling from outfalls and River Ganga. "R" and "L" represent the location of outfalls on the right bank and left bank of the river respectively.

Wastewater samples were taken for three times from each outfall with one hour interval and mixed together to get proper composite wastewater samples. 1L amber glass bottles were used for sample collection for gas chromatography and mass

spectrometric (GC-MS) pesticide analysis following EPA 680 guidelines. The bottles were pre washed with methanol before sampling. Wastewater samples were kept in ice box, transferred to the laboratory on the same day of sample collection, kept with maintained temperature of 4˚C and extracted within 14 days.

Table 1

Sample ID (Right bank of River Ganga)	Location	Northing	Easting
R1	Bandel	23˚02'18"	88˚24'40.10"
R2	Bandel	22˚59'49.10"	88˚24'24.30"
R3	Bandel	22˚57'11.80"	88˚24'20.20"
R4	Bandel	22˚55'62.56"	88˚23'49.30"
R5	Chinsura	22˚54'45.60"	88˚23'53.40"
R6	Chinsura	22˚54'28.50"	88˚24'2.30"
R7	Chinsura	22˚52'32.80"	88˚23'21.90"
R8	Chandannagar	22˚51'24.90"	88˚22'10.70"
R9	Rishra	22˚43'27.20"	88˚21'20.20"
R10	Bally	22˚39'17.74"	88˚20'49.12"
R11	Bally	22˚38'34.40"	88˚21'9.30"
R12	Belur	22˚37'11.20"	88˚21'39.20"
R13	Howrah	22˚34'35.10"	88˚20'24.20"
R14	Howrah	22˚34'22.80"	88˚20'13"
R15	Howrah	22˚34'13.40"	88˚20'3.60"
R16	Howrah	22˚33'38.30"	88˚19'32.90"

Table 2

Sample ID (Left bank of River Ganga)	Location	Northing	Easting
L1	North Barrackpore	22˚46'20.90"	88˚20'10"
L2	Barrackpore	22˚46'10.40"	88˚20'20"
L3	North Barrackpore	22˚45'54.40"	88˚20'43"
L4	North Barrackpore	22˚45'2.90"	88˚21'54"
L5	Baranagar	22˚40'32.90"	88˚21'47.30"
L6	Baranagar	22˚38'11"	88˚21'45.54"
L7	Chitpur	22˚36'28.30"	88˚22'5.60"
L8	North Kolkata	22˚35'37"	88˚21'6.60"
L9	Metiaburuj	22˚33'1.36"	88˚19'26.77"
L10	Garden reach	22˚33'1.69"	88˚17'24.90"
L11	Behala	22˚31'43.50"	88˚14'52.50"
L12	Behala	22˚31'27.10"	88˚14'45.40"

2.2 Sample extraction and analysis

All the wastewater samples were extracted using liquid-liquid extraction methodology. Dichloromethane (DCM) was used as organic solvent. 500 mL from the 1L of collected sample were taken into a conical flux along with 5 gm of Sodium Chloride (NaCl) and 50 ml of DCM and shaken well for 2-3 mins for a proper separation of organic layer. The organic layer was extracted in a 250 mL conical flux passing through Sodium Sulfate (Na_2SO_4) and evaporated to dry at 65˚C. The dried residues were restored to 5 mL of Ethyl Acetate. After that the extracted samples were transferred to 2 mL volume vials for GC-MS analysis.

Extracted wastewater samples were analyzed for pesticides using Thermo Fisher Scientific ISQ 7000-Trace 1300 Single Quadrupole Mass Spectrometer. Helium was the carrier gas. Emparta grade Ethyl Acetate was used for syringe wash, blank and preparatory blank. Injector port temperature was kept 285˚C and operating mode was constant temperature split less (CT-split less). The ramp temperature was initially 70˚C with holding time 1 minute. Then raised at a rate of 25˚C per minute to 150˚C, then at a rate of 10˚C per minute to 220˚C and lastly at a rate of 15˚C per minute to 280˚C with holding time of 5 minutes. Sample injection volume was set up at 2µL. Laboratory evaluation of all the extracted samples were conducted using certified pesticide mix (EPA 8080 Pesticide Mix) of 17 pesticides (Aldrin, α, β, γ, δ-BHC, Dieldrin, Endosulfan– I, II and Sulfate, Endrin, Endrin Aldehyde, Heptachlor, Heptachlor Epoxide, Methoxychlor, 4,4"-DDD, DDE, DDT) and Single Ion Monitoring method (SIM method).

Table 3

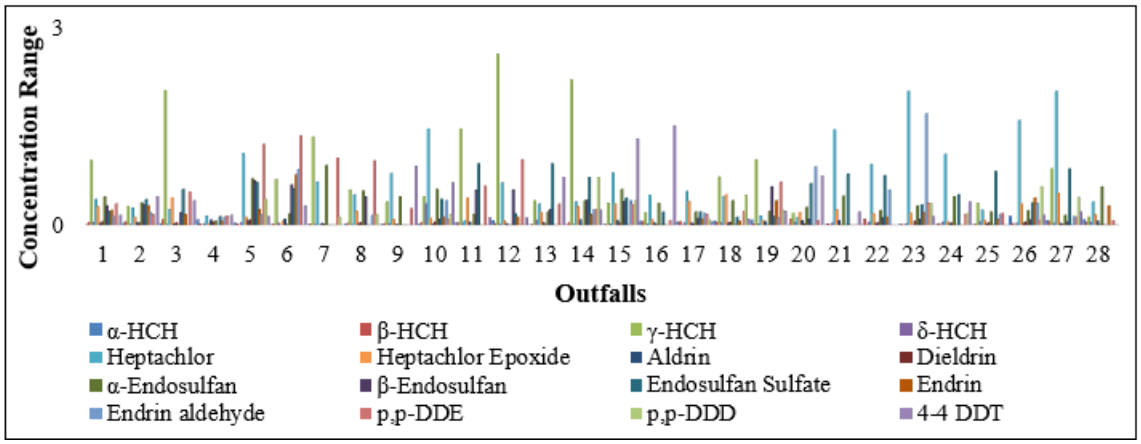
Pesticide names	*RT*	*Characterization ions for quantitation*		
		Q_1	Q_2	Q_3
α - BHC	9.67	181	183	219
β – BHC	9.67	181	183	219
γ - BHC	9.67	181	183	219
δ - BHC	9.67	181	183	219
Heptachlor	11.64	100	272	274
Heptachlor Epoxide	12.95	81	353	355
Aldrin	12.27	66	263	265
Dieldrin	13.94	79	81	263
Endosulfan - I	13.54	195	239	241
Endosulfan - II	14.41	159	195	241
Endosulfan Sulfate	15.02	273	271	239
Endrin	14.28	81	263	263
Endrin Aldehyde	14.68	67	345	250
4,4" - DDE	13.83	246	248	318
4,4" - DDD	14.46	235	237	165
4,4" - DDT	14.99	235	165	237

2.3. Quality assurance and quality control (QA and QC)

Necessary actions for quality assurance and control were performed. Prevention of sample contamination was taken care of. 100% pure HPLC grade distilled water was considered for preparatory blank. Seven point calibration curve of mix pesticide standard solution were made (R^2 = 0.9999). Calibration of instrument were done for each batch of sample analysis. Injector syringe was washed after every ten injections with ethyl acetate. Limit of detection (LOD) and limit of quantification (LOQ) were ranged between 0.01-10 µg/L. Recovery test was performed three times for each samples to reach the accuracy.

3. Results

In the present study pesticides present in municipal wastewater and their level of contamination were identified by gas chromatography-mass spectrometry analysis. It is to be noted that the approach of the study is restricted to sixteen numbers of pesticides. The extension of the study may be conducted applying separate pesticide standard for individual analyte and also high- performance liquid chromatography but for this study these are beyond the scope.



Identified pesticides and their concentration in the outfalls on both the banks of Ganga river:

Among the twenty eight outfalls chosen in the study, sixteen of them are located on the right bank of the river and twelve of them are in left bank. Pesticides were found in the wastewaters from municipality outfalls in following order: Endosulfans > DDTs > Heptachlors > HCHs > Endrin > Aldrin. Concentration of Hexachlorohexane are relatively higher in the outfalls on right bank side compared to left bank (11.5 µg/L). Heptachlor showed higher concentration on the left bank side outfalls (10.2 µg/L). Concentration of Aldrin and Dieldrin are found to be more or less same in all the municipality outfalls distributed on both banks. DDTs were recorded with a concentration of 4.9 µg/L instead of its restricted use.

HCHs:

HCHs comprises of α-HCH + β-HCH + γ-HCH + δ-HCH. Concentration of HCHs vary between UN (Undetected) to 2.05 µg/L dominated by γ-HCH in left and right bank's municipality outfalls. Higher concentration of Lindane or γ-HCH (2.03 µg/L) indicates its ongoing uses. It is widely used to control insects for different commercial crops in agriculture as well as to treat skin irritation and rashes due to scabies and lice. Previous literatures on the concentration analysis of pesticides in Ganga river (Chakraborty et. al 2016 and Bhattacharyya et. al 2021) also documented high concentration of HCH in river water. Municipality drain could be a main source of such concentration.

DDTs:

DDTs (including 4,4"-DDT, 4,4"-DDE and 4,4"-DDD) were detected in several municipal outfalls on both banks of the river. The concentration of total DDTs ranged from undetected levels to 4.9 µg/L. The presence of DDTs, despite its restricted and banned use in many applications, indicates either its persistent nature in the environment or possible illegal/continued usage.

The degradation products DDE and DDD suggest historical application and environmental transformation processes. However, the presence of parent compound DDT in certain locations indicates relatively recent input sources. Municipal wastewater carrying domestic and agricultural runoff may act as a pathway for such contaminants entering the river system.

Endosulfans:

Endosulfan and its derivatives (Endosulfan I, II, and sulfate) were found to be the most dominant pesticides among all detected compounds. Concentrations varied significantly across different outfalls, with maximum values indicating substantial contamination.

The persistence of Endosulfan sulfate, a degradation product, highlights its resistance to environmental breakdown and inefficiency of conventional wastewater treatment systems in removing such compounds. Since Endosulfan has been widely used in agriculture, its presence in municipal wastewater suggests runoff from agricultural lands and improper disposal practices.

Heptachlor and Heptachlor Epoxide:

Heptachlor and its epoxide form were detected in both left and right bank outfalls. The epoxide form, being more stable, indicates transformation of the parent compound in the environment. Concentrations up to 10.2 µg/L were observed, particularly in left bank outfalls.

These compounds are known for their persistence and bioaccumulation potential, posing long-term ecological risks. Their occurrence in municipal wastewater suggests mixed sources including agricultural runoff and industrial discharge.

Aldrin, Dieldrin and Endrin:

Aldrin and Dieldrin were detected at relatively lower but consistent concentrations across all sampling locations. These compounds are known to transform into more stable forms (e.g., Aldrin to Dieldrin), which explains their simultaneous presence.

Endrin and its aldehyde derivative were also identified, indicating historical usage and environmental persistence. Although concentrations were not extremely high, their toxic nature and tendency to bioaccumulate make them environmentally significant.

4. Discussion

The study clearly demonstrates that municipal outfalls act as significant carriers of pesticide residues into the river Ganga. The presence of multiple classes of pesticides, including banned and restricted compounds, highlights the complexity of contamination sources.

4.1 Source Identification

The detected pesticides originate from:

- Agricultural runoff (major contributor)

- Domestic wastewater (use of insecticides, repellents)
- Industrial discharge (pesticide manufacturing units)
- Improper disposal practices

Municipal drainage systems act as a convergence point for all these sources, ultimately discharging untreated or partially treated wastewater into the river.

4.2 Efficiency of Wastewater Treatment

The findings indicate that:

- Conventional sewage treatment plants are **not fully effective** in removing pesticide residues
- Many compounds persist even after partial treatment
- Lack of advanced treatment technologies (e.g., activated carbon, advanced oxidation) contributes to this issue

4.3 Environmental Implications

The presence of pesticide residues in wastewater poses several risks:

- **Aquatic toxicity** affecting fish and microorganisms
- **Bioaccumulation** in the food chain
- **Human health risks** through contaminated water use
- Increased burden on **drinking water treatment systems**

Even though concentrations may not always indicate acute toxicity, long-term exposure can lead to chronic environmental impacts.

5. Conclusion

This study provides a comprehensive assessment of pesticide residues in municipal wastewater discharging into the river Ganga through multiple outfalls in West Bengal. The results indicate that a wide range of pesticides, including banned and persistent organic pollutants, are present in untreated or partially treated wastewater.

Endosulfans and DDTs were found to be the dominant contaminants, followed by Heptachlor, HCHs, and other organochlorine pesticides. The study highlights that municipal outfalls serve as critical pathways for transporting these pollutants into the river system.

The inefficiency of conventional wastewater treatment systems in removing such contaminants underscores the need for advanced treatment technologies and stricter regulatory monitoring. Additionally, better management of agricultural practices and public awareness regarding pesticide usage are essential to reduce environmental contamination.

The findings of this study can serve as a baseline for future monitoring programs and policy formulation aimed at improving water quality and protecting aquatic ecosystems.

References

[1] Qi, W., Singer, H., Berg, M., Müller, B., Pernet-Coudrier, B., Liu, H., & Qu, J. (2015). Elimination of polar micropollutants and anthropogenic markers by wastewater treatment in Beijing, China. *Chemosphere*, *119*, 1054-1061.

[2] Loos, R., Carvalho, R., António, D. C., Comero, S., Locoro, G., Tavazzi, S., ... & Gawlik, B. M. (2013). EU-wide monitoring survey on emerging polar organic contaminants in wastewater treatment plant effluents. *Water research*, *47*(17), 6475-6487.

[3] Tran, N. H., Reinhard, M., & Gin, K. Y. H. (2018). Occurrence and fate of emerging contaminants in municipal wastewater treatment plants from different geographical regions-a review. *Water research*, *133*, 182-207.

[4] Qi, W., Singer, H., Berg, M., Müller, B., Pernet-Coudrier, B., Liu, H., & Qu, J. (2015). Elimination of polar micropollutants and anthropogenic markers by wastewater treatment in Beijing, China. *Chemosphere*, *119*, 1054-1061.

[5] Loos, R., Carvalho, R., António, D. C., Comero, S., Locoro, G., Tavazzi, S., ... & Gawlik, B. M. (2013). EU-wide monitoring survey on emerging polar organic contaminants in wastewater treatment plant effluents. *Water research*, *47*(17), 6475-6487.

[6] Petrie, B., Barden, R., & Kasprzyk-Hordern, B. (2015). A review on emerging contaminants in wastewaters and the environment: current knowledge, understudied areas and recommendations for future monitoring. *Water research*, *72*, 3-27.

[7] Gros, M., Blum, K. M., Jernstedt, H., Renman, G., Rodríguez-Mozaz, S., Haglund, P., ... & Ahrens, L. (2017). Screening and prioritization of micropollutants in wastewaters from on-site sewage treatment facilities. *Journal of hazardous materials*, *328*, 37-45.

[8] Eriksson, E., Auffarth, K., Eilersen, A. M., Henze, M., & Ledin, A. (2003). Household chemicals and personal care products as sources for xenobiotic organic compounds in grey wastewater. *Water Sa*, *29*(2), 135-146.

[9] Wluka, A. K., Coenen, L., & Schwarzbauer, J. (2017). Screening of organic pollutants in urban wastewater treatment plants and corresponding receiving waters. *Water Science and Technology*, *76*(4), 832-846.

[10] Blum, K. M., Andersson, P. L., Renman, G., Ahrens, L., Gros, M., Wiberg, K., & Haglund, P. (2017). Non-target screening and prioritization of potentially persistent, bioaccumulating and toxic domestic wastewater contaminants and their removal in on-site and large-scale sewage treatment plants. *Science of the total environment*, *575*, 265-275.

[11] Huang, Y. H., Dsikowitzky, L., Yang, F., & Schwarzbauer, J. (2020). Emerging contaminants in municipal wastewaters and their relevance for the surface water contamination in the tropical coastal city Haikou, China. *Estuarine, Coastal and Shelf Science*, *235*, 106611.