

Research Article

An Assessment of Physicochemical Characteristics and Heavy Metals Concentrations of Effluent Water Discharge in Plastic – Sand Brick Production

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Abstract

The physicochemical parameters and heavy metals concentrations of effluent water discharge during production of plastic – sand bricks were examined. The samples were collected in sterile containers from the recycled wastewater collector system and was bench marked with a controlled water sample collected from the Institute of Pollution Studies laboratory, Rivers State University campus. The containers were first rinsed with the sample water before the final collection. The samples collected were taken in an iced - packed cooler to the Institute of Pollution Studies laboratory, Rivers State University, Port Harcourt, where the analysis was performed. The physicochemical parameters analysis results show that temperature (28.90 °C), Turbidity (114 NTU), Conductivity level (48.4 µS/cm), Salinity (0.05 mg/l), Total Dissolved Solids, TDS, (81mg/l), Total Hardness level (15.3 mg/l) and alkalinity level (2 mg/l) are within the regulatory authority allowed limits although pH level of 5.04 for the plastic brick effluent was too acidic. Metallic ions such as Chloride (4.5 mg/l), Sulphate (3.21 mg/l), Nitrate (1.35 mg/l), Phosphate (0.08 mg/l), Manganese (<0.038 mg/l), calcium (5.172 mg/l), Magnesium (0.578 mg/l) and iron (<0.005 mg/l) were also examined and were found to be within the regulatory limits. This study supports the production of plastic – sand bricks as an environmental management tool since the effluent parameters except pH fall within the regulatory limits and the plastic wastes recycled to bricks in sound environmental method. It is recommended that before any discharge of the effluent to the environment, all discharges should be monitored and analysed to avoid discharging toxic effluent to the environment since waste sludges used as additives may contain elevated levels of certain pollutants.

Keywords

Effluent Quality, Environmental Monitoring, Heavy Metals, Plastic–sand Bricks, Waste Recycling

1. Introduction

Environmental experts and practitioners make efforts to keep environment as pristine as it could be. The production of plastic – sand bricks is an option of environmental waste management which tries to manage municipal solid waste

(MSW) generated through different processes. Plastic, a non-biodegradable polymer, persists in the environment due to its resistance to natural degradation" [1]. As conventional plastics are persistent in the environment, improperly dis-

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posed plastic materials are a significant source of environmental pollution, potentially harming life [2]. When vast majority of plastic wastes are not recycled, millions of tons of them end up in landfills. Many a times, trash is thrown away too easily without a second thought and the negative impact on our environment. Environmental best practise suggests that it make sense to recycle as much of plastic as possible rather than just reduce the amount of trash we bury.

Purpose: The purpose of this study is to assess the physicochemical and heavy metal concentrations of effluent water discharged during plastic–sand brick production to evaluate its compliance with environmental regulatory standards. This study is significant as it bridges the gap between sustainable waste management and environmental safety by providing empirical data on effluent quality from plastic–sand brick production, an emerging eco-friendly practice in urban settings

The world produces over 400 million tonnes of new plastic every year, with some estimates placing the figure at 430 million metric tons. Around half of this plastic is single-use, and a significant portion ends up in the environment, with an estimated 11 million tonnes entering lakes, rivers, and oceans annually. This is about 120 million tons more than in 2010 [3, 4].

Global cumulative production of plastic is forecast to grow from 9.2 billion tons in 2017 to 34 billion tons by 2050. It is estimated that about 1.1 billion tons of plastic will be produced globally by 2050 annually if the level of plastic produced or mismanaged is not checked [5]. It is imperative to reduce volume of plastic produced or mismanaged and increase the level of plastic waste recycling currently estimated at less than 10 percent.

Increased industrialization, increasing human population, expanding food production/processing and changing lifestyles leads to increased waste generation in Port Harcourt metropolis [6]. The composition of these municipal solid waste includes food waste, paper, polyethylene, textile, plastic, metals, and others. Thus, a proper waste management system is necessary to keep our environment friendly. One method of sound municipal solid waste management is recycling of plastic waste through production of bricks. Recycling is a process of converting or manufacturing new products from a product that has originally served its purpose. Plastic waste can be recycled into different products such as bricks, asphalts, biofuel, T-shirt, etc. The chemical bonds between the molecules that comprises plastic not only make them resilient but also impervious to natural degradation [7]. [8] carried out experimental work on bricks made of non – recyclable waste thermoplastic granules consisting of 0 to 10% by weight fly ash, 15% cement and sand making up the reminder. The resulting bricks were found to be light weight, porous, low thermal

conductivity and appreciable mechanical strengths. [9] worked on different types of plastic wastes processed into composite brick alongside with brick made with one hundred percent (100%) clay, it was observed that the maximum compressive load sustained by the polypropylene/rubber composite brick is 17.05 tons followed by Low Density Polyethylene (LDPE) /Rubber composite brick with 16.55 tons which is much higher than the clay brick which sustained only 9.03 tons. [10] produced plastic – sand bricks from varied ratios of plastic waste and sand alongside brick made with cement and sand. It was discovered that the plastic sand bricks produced were of appreciable mechanical properties as conventional cement – sand bricks. Thus, plastic wastes were and can be effectively converted into useful building materials. This method can help mitigate environmental pollution and further decrease the problem of waste plastic in the society as reported by [9].

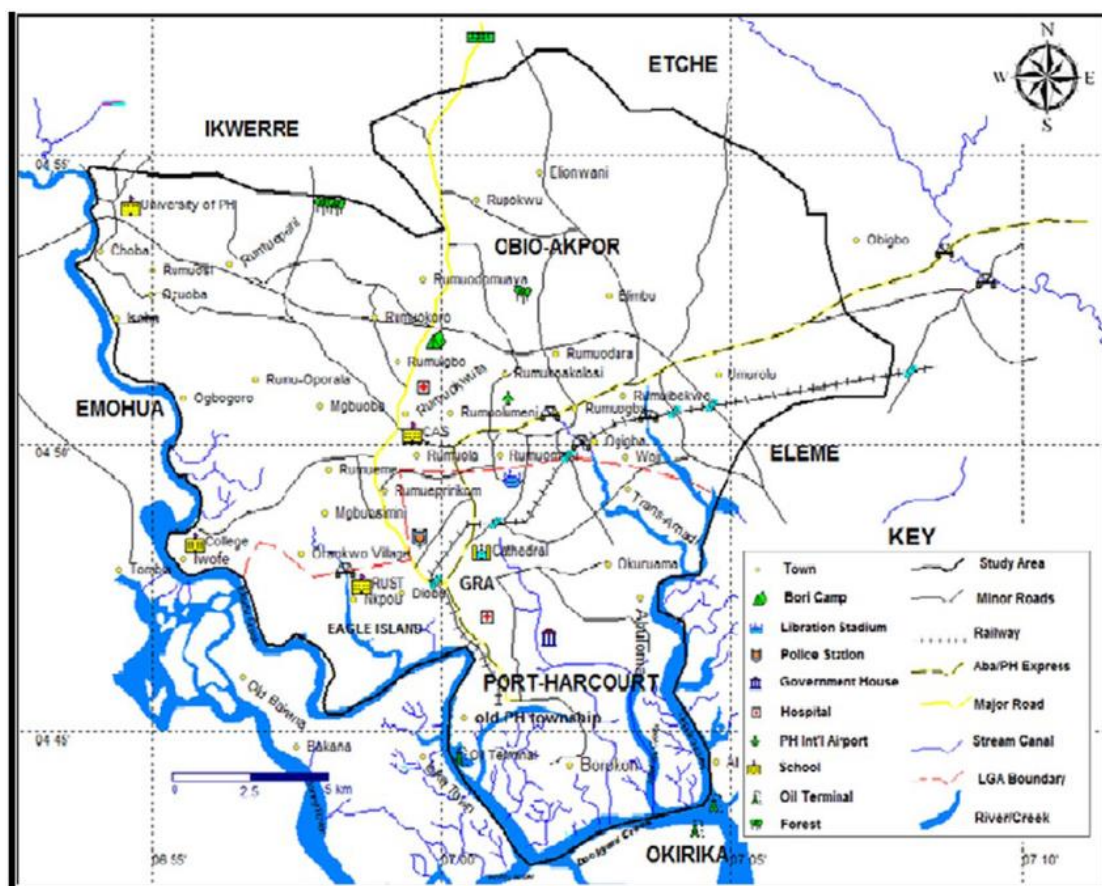
However, the effluent water generated during the process can pose environmental challenge if not properly treated and/or mismanaged. This study analyzed the level of heavy metal, and other physicochemical parameters of the effluent water discharged into the environment from the process of production of plastic – sand brick.

2. Materials and Methods

2.1. Description of Study Area

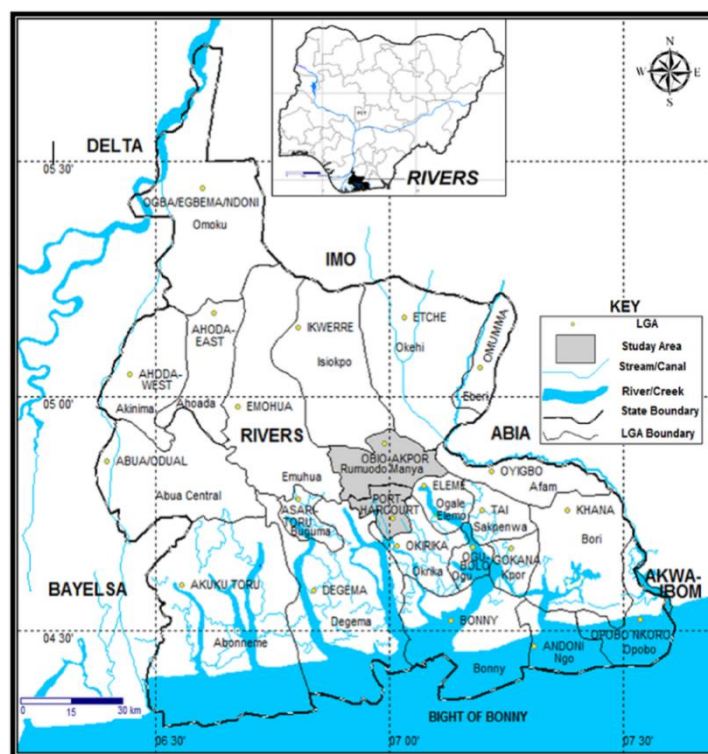
Port Harcourt metropolis comprises of the capital city and adjoining cities of the capital city of Rivers State, Nigeria. It is located on latitudes $4^{\circ}51'30''$ N and $4^{\circ}57'30''$ N and longitudes $6^{\circ}50'00''$ E and $7^{\circ}00'00''$ E. Rivers State with Port Harcourt as its capital, is bounded on the south by the Atlantic Ocean, west by Bayelsa and Delta States, north by Imo, Abia and Anambra states and east by Akwa Ibom state [11].

Port Harcourt is a metropolitan city and capital of Rivers State, occupying approximately 1811.6 km² area, with a population of about 7.4 million (National Population Commission, 2023). Port Harcourt metropolis constitutes the state's main city with one of the largest seaports in the Niger Delta region, thus, being the regional center of administration, commerce and industrial activities [11, 12]. It is situated between Latitude 4450N and 4550 N, and Longitude 6550 E and 7050 E in the state, occupying the entrance of the Bonny River. The city is bounded in the north by Abia and Imo states, east by Akwa Ibom state; west by Bayelsa state; and south by the Atlantic Ocean. Its estimated mean altitude is 12km above the average sea level, lying between the Dockyard creek/Bonny River and the Amadi creek [11].



Source: Google Earth, 2022.

Figure 1. Map of Port Harcourt Metropolis.



Source: Google Earth, 2022.

Figure 2. Map of Rivers State Showing Study Area.

2.2. Sample Collection

The research utilized experimental research design where samples of effluent water were collected from the recycled wastewater collector system and tap water from the Institute of Pollution Studies laboratory, Rivers State University, Port Harcourt, which serves as a control water sample. Sample containers were first rinsed with the recycled wastewater before final samples were collected. The collected samples were taken in an ice packed cooler to the Institute of Pollution Studies laboratory, Rivers State University, Port Harcourt for analysis and evaluation of physicochemical characteristics and metals concentration to determine the quality of discharged effluent water and ascertain that the discharged effluent follows and within the permissible regulatory standards.

2.3. Physico-chemical Parameters

The physicochemical characteristics of the water samples were assessed against regulatory standards. In this study, pH, electric conductivity, total dissolved solids were determined

using their respective meters. pH was measured using a pH meter as per HANNA H19125; conductivity and total dissolved salts were determined using calibrated conductivity meter (HANNA conductivity meter). Turbidity measurements were determined using a portable turbidity meter (APHA, 2012). Laboratory burette titration was used to evaluate the sample total hardness and standard methods were deployed to determine total alkalinity, chloride, nitrate, sulphate and major cations from the effluent water. The Atomic Absorption Spectrophotometer (AAS), recorded as the mean value, was used to determine metal concentrations in the sample.

3. Results

The levels of physico- chemical properties and heavy metals of both the plastic – sand brick effluent wastewater and control water were analysed and results presented in Table 1. The descriptive analysis of both effluent and control water physico – chemical parameters are presented in Table 2 and Figure 3.

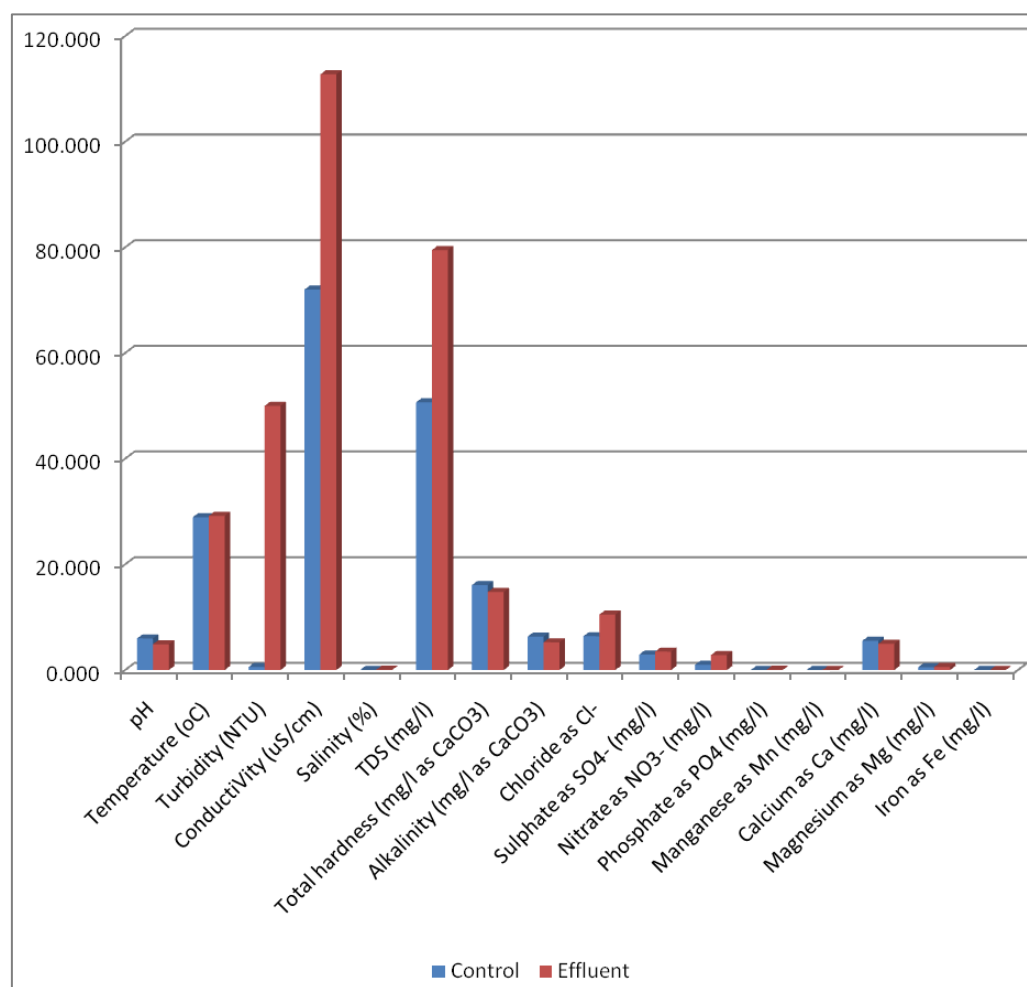


Figure 3. Mean Data of Physico-chemical Parameters of Control and Effluent Water.

Table 1. Levels of Physicochemical Parameters for Control and Effluent Water.

PARAMETER	CONTROL	EFFLUENT	FME _{env} LIMIT (1991)	WHO (2022)
Ph	6.08	5.04	6- 9	
Temperature (°C)	28.7	28.9	<40	
Turbidity (NTU)	0.3	114	-	
Conductivity (µS/cm)	7.3	114	-	
Salinity (‰)	0.01	0.05	-	
Total Dissolved Solids (mg/l)	52	81	2000	
Total Hardness (mg/l)	16.7	15.3	-	
Alkalinity (mg/l)	6	2	-	
Chloride (mg/l)	6.4	4.5	600	
Sulphate (mg/l)	1.8	3.21	1000	>500/2003
Nitrate (mg/l)	0.68	1.35	20	50 /2011
Phosphate (mg/l)	0.05	0.08	10	
Manganese (mg/l)	0.0002	0.038	-	0.4
Calcium (mg/l)	5.8	5.172	-	
Magnesium (mg/l)	0.532	0.578	-	
Iron (mg/l)	0.005	0.005	20	

Table 2. Descriptive Analysis of Physicochemical Parameters of Control and Effluent Water.

	Ph	Temperature (°C)	Turbidity (NTU)	Conductivity (µS/cm)	Salinity (‰)	TDS (mg/L)	Total hardness (mg/L as CaCO ₃)	Alkalinity (mg/L as CaCO ₃)
Control	6.080	28.700	0.300	73.000	0.030	52.000	16.700	6.000
	5.820	29.000	0.700	73.000	0.030	51.000	16.500	7.000
	6.040	29.100	0.800	70.000	0.030	49.000	15.000	6.000
Mean	5.980	28.933	0.600	72.000	0.030	50.667	16.067	6.333
Effluent	5.040	28.900	114.000	114.000	0.050	81.000	15.300	2.000
	4.490	29.200	48.400	112.000	0.050	78.000	14.500	7.000
	5.010	29.300	23.000	111.000	0.050	79.000	14.700	6.000
	4.980	29.300	14.600	114.000	0.050	80.000	14.600	6.000
Mean	4.880	29.175	50.000	112.750	0.050	79.500	14.775	5.250
Control	5.980	28.933	0.600	72.000	0.030	50.667	16.067	6.333
Effluent	4.880	29.175	50.000	112.750	0.050	79.500	14.775	5.250

Table 2. Continued.

	Chloride as Cl ⁻	Sulphate as SO ₄ ⁻ (mg/L)	Nitrate as NO ₃ ⁻ (mg/L)	Phosphate as PO ₄ ⁻ (mg/L)	Manganese as Mn (mg/L)	Calcium as Ca (mg/L)	Magnesium as Mg (mg/L)	Iron as Fe (mg/L)
Control	6.400	1.800	0.680	0.000	<0.002	5.800	0.532	0.000
	7.400	3.700	1.300	0.000	<0.002	5.713	0.544	0.000
	5.400	3.300	0.990	0.050	<0.002	5.123	0.531	0.000
Mean	6.400	2.933	0.990	0.017	0.000	5.545	0.536	0.000
Effluent	4.500	3.210	1.350	0.080	0.038	5.172	0.578	0.000
	6.900	4.400	2.170	0.070	0.023	4.871	0.564	0.005
	7.900	2.900	5.060	0.060	<0.002	4.960	0.564	0.000
	22.700	3.400	2.770	0.100	<0.002	4.893	0.578	0.000
Mean	10.500	3.478	2.838	0.078	0.031	4.974	0.571	0.001
Control	6.400	2.933	0.990	0.017	0.000	5.545	0.536	0.000
Effluent	10.500	3.478	2.838	0.078	0.031	4.974	0.571	0.001

4. Discussion

The result shows that some physico- chemical parameters have values that are negligible while others with higher values will require further treatment to meet regulatory standards before discharge to the environment. The pH, which is a measure of the hydrogen ion activity of the water, is an indicator of the acidic or alkaline nature of a water body. It is one of the most important parameters commonly measured in either natural or wastewater to determine the quality status of such water. The pH analysis result from the effluent water was 5.04. This value falls below the regulatory standard of both the Nigerian Upstream Petroleum Regulatory Commission, (NUPRC) and the World Health Organisation (WHO) standards, which ranges between 6.5 and 8.5 as an acceptable or permissible limit of effluent water to be discharged to the environment [13]. The result from the control sample was 6.06 which is in line with the permissible limit.

The effluent water had a temperature average value of 28.9°C and is within the permissible limit of the regulatory authority which ranged at less than 40 °C as acceptable limit for effluent water. Control sample had 28.7 °C.

The average turbidity, which is a measurement of the amount of light that is scattered by material in the water when a light is shield through the water sample, shows relative clarity of the liquid. The analysis result from the effluent water was 114NTU, a value higher than the permissible limit of less than 10 and 15 for inland and near shore environments [14].

The average salinity of the effluent water was also analysed.

Salinity refers to the concentration of dissolved salts in water, which may vary based on ion content. High ion or chloride concentrations results in water hardness and acidity of the surrounding water, which may be harmful for consumption depending on source of water supply for daily survival [15]. The result of the effluent water salinity shows 0.05% which is within the permissible limit of the regulatory authority of 600mg/l - 2000mg/l for inland and near shore environments. The total dissolved solids, TDS, of the effluent water was 81mg/l. This value is within the permissible limit of 2000mg/l – 5000mg/l for inland and near shore environments respectively. The test results for total hardness and alkalinity of effluent water were 15.3mg/l and 2mg/l respectively. These values are well within the permissible limits of 600g/l – 2000mg/l for inland and near shore water environment respectively.

The mean chloride, Cl⁻, concentration level of the effluent water was 4.5mg/l. This is less than the permissible limit of 600mg/l – 2000mg/l for inland and near shore water environment.

The mean concentration of sulphate, SO₄⁻, nitrate, NO₃⁻, and phosphate, PO₄⁻ were 3.2mg/l, 1.35mg/l and 0.08mg/l respectively, which are all less than and within permissible limits of 1000mg/l, 20mg/l and 10mg/l respectively for inland and near shore water environment.

Manganese, Mn, mean concentration, Calcium, Ca, Magnesium, Mg and Iron, Fe, limits of effluent water were 0.038mg/l, 5.172mg/l, 0.578mg/l and 0.005mg/l respectively and are all within regulatory allowed limits of 0.0mg/l – negligible values for Mn, and Mg and 50mg/l for Ca and 1.0mg/l for Fe respectively.

Heavy metal concentrations of Copper, Cu, Chromium, Cr, Manganese, Mn and Cadmium, Cd has been one of the critical concerns in natural environments due to their toxicity and bio magnification attributes [15]. These metallic elements are of public health concern and considered as systemic toxicants that are known to induce multiple organ damage, even at lower levels of exposure [16].

The test findings revealed that the physico- chemical characteristics of the brick's effluent water is all within regulatory permissible limits except for pH, which was found to be more acidic at 5.04. This means that the environment may not be severely affected by the effluent discharge; however, may be affected in the long run if not controlled. This is in line with the findings of [17], in the Niger Delta Waters, which noted that discharges produced waters had high metals ions and total hydrocarbon concentration (THC). [18] reported that produced water discharges in near shore environment in Niger Delta resulted in substantial accumulation of hydrocarbons and microorganisms up to fifty percent (50%) from discharge points.

5. Conclusion and Recommendations

5.1. Conclusion

It is common knowledge that raw effluent wastewater discharge contains high – volume toxic waste when discharged untreated and is detrimental to the environment.

The analysis shows that while most parameters of the plastic-sand brick effluent are within regulatory standards, the acidic pH level requires corrective action before discharge. This underlines the importance of routine monitoring and basic effluent treatment to ensure the environmental safety of this promising waste-to-brick production method.

5.2. Recommendations

Regular monitoring of industrial effluents by regulatory authorities will enhance strict compliance to permissible discharges by industrial players. The study recommends that government should increase awareness and sensitisation of the citizenry on the hazards of unmanaged wastes especially plastic waste to reduce the plastic wastes discharged to the environment. Regulatory authorities and industry players including all other stakeholders, should adopt a participatory strict compliance measure through routine monitoring and inspection/analysis of effluent discharges of any sort before discharging into the environment.

Abbreviations

WHO	WORLD HEALTH ORGANISATION
FMEEnv	Federal Ministry of Environment
APHA	American Public Health Association

Conflicts of Interest

The authors declare no conflicts of interest.

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