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Original article

Assessment of physicochemical parameters and heavy metal concentration in the effuents of sewage treatment plants in Jazan Region, Saudi Arabia

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ABSTRACT

Heavy metals pollution deserves attention even at the lowest concentration due to their toxic effects on the environment and human health. Here we report that the heavy metals and other hazardous compounds such as Cd, Cu, Mn, Zn are detected from sewage waters of three cities in Jazan Region of Kingdom of Saudi Arabia. Sewage water from their Sewage Treatment Plant (STP) was collected and analyzed. Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) method was used to analyze the samples. The Mn was found in Jazan city with a concentration of 0.2198 mg/L, while the lowest is the Cu 0.0182 mg/L. Along with various levels of Cd, Cu, Mn, Zn compound are also in both Sabia and Samtah. In all the cities, Zn was in an elevated level. These findings indicate the discharge of a high concentration of metals in the aquatic ecosystem, affecting the pH, COD, etc., and which would directly impact the Red Sea marine ecosystem and vegetation in and around the Jazan Region.

1. Introduction

The rapid advancement in modern technologies and improved living standards paves the way for a massive demand for natural and artificial resources. This circumstance has increased heavy metals usage as an incorporated product in various household and commercial products. Even in trace amounts, these heavy metals are lethal to humans and animals, which is an alarming situation (Shamuyarira and Gumbo, 2014). The study of heavy metals and their toxicity is crucial in environmental sciences for nearly half a century. The primary route of human exposure to metals is through food and inhaled (Pipi et al., 2018). Prolonged exposure to heavy metals is also the reason for cancer (Kim et al., 2015), Studies conducted on heavy metals related to human diseases show strong evidence of aluminum (Al) from the aquatic system connected to Alzheimer's diseases, which is an inducing factor (Campbell, 2002).Table 1

Heavy metal pollutions in the environment are directly related to anthropogenic activity; heavy metals in the aquatic environment are originated mostly from industrial effluent water and agricultural pesticides. Water has a trace of heavy metals by nature, but crossing the minimum amount results in toxicity and affects the aquatic environment (Kotalova et al., 2020). Heavy metal pollution in water bodies directly connected to the population density and uncontrolled release of polluted water to the environment by growing industries (Al-Mur et al., 2017). Many heavy metal studies are conducted in the marine environment near coastal areas because of the human population's anthropogenic effect (Dai et al., 2007).

The Red Sea coastal areas are contaminated by rapid industrialization for several years (Badr et al., 2009). Recent research denotes, almost 60% of the Red Sea corals are at the brink of risk due to anthropogenic acts (Carvalho et al., 2018). In a recent study, the outlet from Jeddah city through wastewater shows a rapid deposit of heavy metals in the Red Sea from various industries, oil refinery, wastewater treatment plant, and desalination plants, consisting of Chromium, Lead, Zinc ion, Copper, Manganese, Iron (Al-Mur et al., 2017). Jizan region, with 250 km of the coastal area, is known for its richness in fishing with 350 species of marine organisms (Said et al., 2014). Heavy metals like Cadmium (Cd), Cobalt (Co), Copper (Cu), Magnesium (Mg), Manganese (Mn), Nickel (Ni), Lead (Pb), Zinc (Zn) cause serious health issue in

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Table 1
Showng the description of STP capacity, sewage input source and type of waste.

No.	Factor	Jizan -A	Sabia-B	Samtah-C
1	Sewage input	38000 m^3	8000 m^3	5000 m^3
2	Plant capacity	20000 m^3	33000 m^3	22500 m^3
3	Source	Jizan & surrounding villages	Sabia & surrounding villages	Samtah & surrounding villages
4	Type	Domestic	Domestic	Domestic
5	Transportation	Ducts & Tankers	Tankers	Tankers
6	Output	To Sea & Irrigation	To Sea & Irrigation	To River & Irrigation

humans such as metabolic and genetic deregulation (Go et al., 2015). Endocrine dysfunctions, adverse tissue response, osteolysis (Leyssens et al., 2017), cytotoxic, genotoxic and apoptotic effects in humans (Abudayyak et al., 2016), oxidative stress, toxicity in osteoblasts (Wang et al., 2020), induce toxicity in human B lymphocyte and induce mutation (Roth et al., 2012), toxicity in lung epithelial cells (Ahamed, 2011), reproductive system (Kumar and Devi, 2018), Parkinson's diseases (Jin et al., 2021) are also reported. Jazan region supplies a huge volume of fisheries to various parts of Saudi Arabia. Apart from this Jazan holds a key oil port, desalination station with various industries. Along with this, Jazan holds a fertile agricultural land that produce numerous vegetables and fruits (Said et al., 2014). There are no previous studies focused in the heavy metals in STP water in the Jazan region since this is the first report of heavy metal analysis from STP wastewater in the Jazan region. This study highlights the level of eight metallic elements (Cd, Co, Cu, Mg, Mn, Ni, Pb, Zn) in the STP along with physical parameters. These findings will help us to understand the current scenario of domestic sewage waters inward and outward in three STP plants located inside the Jazan region and intended to analyze the quantity of heavy metals present in the STP of 3 cities, its discharge quality towards the sea and reusing ability for agriculture using inductively coupled plasma mass spectrometry (ICP-MS).

2. Materials and methods

2.1. Sample collection sites

The three sewage treatment plant investigated in this study are located in Jizan, Sabia, Samtah in Jizan municipality under Jazan region of the Kingdom of Saudi Arabia with geographical location shown in Fig. 1 with a flow rate of 38000 m^3, 8000 m^3, 5000 m^3, which is further used for agriculture and directed towards Red Sea. All these cities together have a population of 16,37,361 (https://www.stats.gov.sa/en/6140). In these three cities, 90% of all sewage is transported to a sewage treatment plant (STP) through ducts and tankers for treatment. These STP involves in various processes like Mechanical filtration Sand and oil removal, Aeration, Sedimentation, Sand separator, chlorination. After treatment, the STP water is released to irrigation and sea. The water samples are collected from the outlet of all three STP from January 2020 to April 2020 for the analysis of physicochemical parameters and heavy metal determination. The sampling sites for the samples are labelled as Jizan- A, Sabia- B, Samtah- C.

2.2. Physico-chemical parameters of wastewater samples

The samples were collected in a 15 ml falcon tube from sites (A, B, C) and kept in an icebox at 4 °C until delivered to the laboratory for analysis. The physical and chemical parameters of the A, B, C samples were measured.

2.3. Analysis of heavy metals in a water sample by ICP MS

The heavy metal analysis was carried out using a Perkin Elmer SCIEX 9000 (USA) ICP-MS-Inductively coupled plasma mass spectrometry technique after its calibration and optimization. A developed Perkin Elmer method was used to calculate the limits of detection (LOD) and quantification (LOQ) of the heavy metals evaluated by the ICP-MS method. The sample liquid was nebulized, and produced aerosols are transported to argon plasma. Ions produced under high temperature are later passed into mass spectrometer to categorize by mass to charge ratio and quantified via electron multiplier detector. All reagents used for the laboratory analysis are received from (Sigma Aldrich, USA).

3. Result

The physicochemical parameters (pH, temperature, electrical conductivity) of samples collected from STP - A, B, C of Jazan region are depicted in (Table 2, 3, 4) and heavy metals (Cd, Co, Cu, Mg, Mn, Ni, Pb, Zn) were analyzed.

3.1. Temperature

The STP water temperature variations occur every day and seasonally due to climate change and various environmental factors. STP water temperature obtained varies from A- (28.62 – 32.91 °C), B – (30.34 – 31.23 °C), C- (30.18 – 31.76 °C) (Table 2).

3.2. pH:

The mean pH values for all the three sites (A, B, C) lies under the permissible range of the WHO referred pH range 6.5–8.5. The range of pH measured from Jan to April 2020 in all the three sites are A – (7.3 ± 0.15–7.5 ± 0.21), B – (7.53 ± 0.18–7.97 ± 0.30), C - (7.61 ± 0.06–7.73 ± 0.09) which is shown in (Table 3).

3.3. Electrical conductivity (EC)

The observed EC values in all the three sampling plants showed an increased level of values in A-3505.51 ± 237.84 μS/cm, B- 2443.63 ± 695.75 μS/cm, C- 2698.21 ± 150.70μS/cm. Conductivity is the way to measure the dissolved ionic compounds in water to conduct electricity.

3.4. Heavy metals concentrations

The heavy metals concentration of the STP – A, B, C are observed through this study Table 5. The Cadmium (Cd) concentration in site-A was found to be 0.0858 mg/L, which is above the WHO guidelines recommended value, which is 0.01 mg/L. Site B has a lesser concentration, but site C records a higher concentration of Cd 0.1223 mg/L.

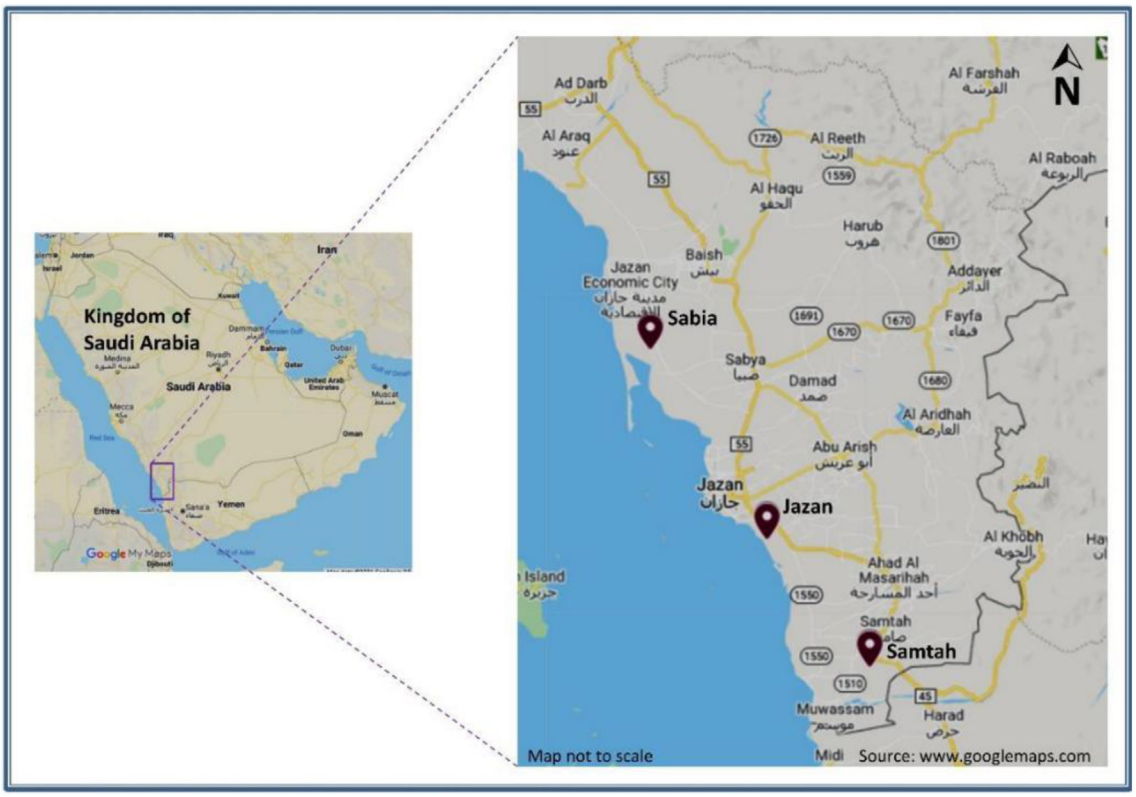

Fig. 1. Figure showing the demographic area of samples isolated from 3 STP situated in Jazan Region.

Table 2
Showing the temperature of the waste water samples from 3 sewage treatment plants inside Jazan region on Red Sea coast.

Sampling month	Jizan (°C)	Sabia (°C)	Samtah (°C)
January	28.62 ± 1.48	30.49 ± 0.7	31.09 ± 1.20
February	28.83 ± 1.46	30.83 ± 0.81	31.76 ± 1.16
March	30.34 ± 1.57	31.23 ± 0.96	30.93 ± 1.23
April	32.91 ± 0.70	30.34 ± 0.96	30.18 ± 0.88
Range	28.62 – 32.91	30.34 – 31.23	30.18 – 31.76

Table 3
Showing the pH of the waste water samples from 3 sewage treatment plant inside Jazan region on Red Sea coast.

Sampling	Jazan	Sabia	Samtah
Month			
January	7.3 ± 0.15	7.59 ± 0.14	7.61 ± 0.06
February	7.5 ± 0.24	7.53 ± 0.18	7.66 ± 0.07
March	7.5 ± 0.22	7.80 ± 0.15	7.71 ± 0.08
April	7.5 ± 0.21	7.97 ± 0.30	7.73 ± 0.09
Range	7.3 ± 0.15	7.53 ± 0.18	7.61 ± 0.06
	– 7.5 ± 0.21	– 7.97 ± 0.30	– 7.73 ± 0.09

Table 4
Showing the conductivity of the waste water samples from 3 sewage treatment plant inside Jazan region on Red Sea coast.

Sampling	Jazan-A/EC (μS/cm)	Sabia-B/EC (μS/cm)	Samtah-C/EC (μS/cm)
Month			
January	3505.51 ± 237.84	2443.63 ± 695.75	2657.74 ± 120.60
February	3365.67 ± 251.57	2139.9 ± 83.16	2698.21 ± 150.70
March	3451.93 ± 239.59	2174.76 ± 92.55	2652.25 ± 81.10
April	3450.25 ± 237.81	2038.4 ± 145.42	2607.74 ± 89.24

4. Discussion

Heavy metal concentration in all three STP were analyzed in this study Jizan-A, Sabia-B, and Samtah-C from the Jazan region. The results show an elevated level of Cd and Mn from the STP outlet compared to permissible standards, and Cu, Cd, Zn are observed under the permissible standards. Metals like Co, Mg, Ni, Pb are not detected from the samples. Heavy metals seem to increase in the Jizan-A STP than the other two sites, due to the high population of the city. This water from the STP is not suitable for agriculture purposes due to previous findings of adverse effects for humans from STP treated water in various countries. The microbial degradation in the STP water relay on pH, temperature, bio-organic compounds and microflora types (Kinuthia et al., 2020). In this, pH and temperature together play a vital role in biodegradation reactions under enhanced bio-organic compounds. Increased pH value may interrupt in the disinfection of water by chlorination (Ma et al., 2020). The highest temperature range was recorded on site A, which is elevated up to 32.91 ± 0.70 above the WHO range, while site B and C falls within the WHO range of 20 to 32 °C (Kinuthia et al., 2020). Releasing STP treated water with elevated temperature into water bodies will increase ecological reactions in water along with reduced oxygen solubility and increased odour because of anaerobic reaction (Ma et al., 2020).

The rise in Cd concentration in mostly because of industrial effluents mixing with the waste water channels (Nassef et al., 2007). Apart from this, the regular usage of cadmium phosphatic fertilizers are responsible for a significant amount of Cd settlement in soil and water bodies. A higher concentration of Cd leads to kidney dysfunction, high blood pressure and organ damage (Nassef, 2007, Rajappa et al., 2010). Copper (Cu) is an important element in the human body for enzymes and haemoglobin production. In this study, Cu concentration in site A-0.0182 mg/L, B-0.0066 mg/L, C-0.0027 mg/L shows a lesser value compared to

Table 5
Showing the heavy metals concentration of input and output of three locations Jizan-A, Sabia-B and Samtah-C sewage treatment plant inside Jazan region on Red Sea coast analyzed by ICP-MS analysis.

Location	Cd (mg/L)	Co (mg/L)	Cu (mg/L)	Mg (mg/L)	Mn (mg/L)	Ni (mg/L)	Pb (mg/L)	Zn (mg/L)
Jizan-A input	0.0858	ND	0.0182	ND	0.2198	ND	ND	0.1772
Jizan-A output	ND	ND	0.0128	ND	0.1082	ND	ND	0.1278
Sabia-B input	0.0065	ND	0.0066	ND	0.1847	ND	ND	0.169
Sabia-B output	0.0044	ND	0.0038	ND	0.0708	ND	ND	0.1052
Samtah-C input	0.1223	ND	0.0027	ND	0.1044	ND	ND	0.1254
Samtah –C output	0.0408	ND	0.0029	ND	0.0695	ND	ND	0.095

WHO standards of 0.20 mg/L(Chaoua et al., 2019), even the concentration of Cu is lesser, but the source of copper may be from the industrial area output water (Haftu and Sathishkumar, 2020).

Manganese (Mn) concentration is also observed in the current study in all the three study sites A-0.2198 mg/L, B- 0.1847 mg/L, C- 0.1044 mg/L. Site A showed a higher value when compared to the Mn permissible limit (0.20 mg/L; WWF (2007)) in wastewater (Ahmad et al., 2019). Site B is on the margin of permissible limit that needs to be monitored regularly, and site C shows a lesser value than the permissible limit. Mn is toxic to human health in elevated concentrations, and it causes neurological disorders as manganism which is very similar to Parkinson disease (Said et al.2014). Zinc (Zn) concentration from the site A-0.1772 mg/L, B-0.169 mg/L, C-0.1254 mg/L shows lesser value comparably from the permissible limit 2 mg/L of FAO (1985), WHO/FAO (2007) (Ahmad et al., 2019). Metals like Zn are important nutrients for human health and turns toxic in higher concentration. Elevated level of zinc can suppress immune function and high-density lipoprotein levels (Chaoua et al., 2019). Zn notes to be a worthy metal in microbial metabolism and vital metal in human growth and bone development (Haftu and Sathishkumar, 2020). All these three site A,B and C sewage waters from STP are discharged to agriculture and Red Sea from the study sites. The plants grow on wastewater irrigation leads to potential toxic accumulation and leads to various disorders in humans, previously wheat plants accumulated toxic metals grown under the treated wastewater from STP (Dogan et al., 2010; Liu et al., 2005). Apart from Cadmium (Cd), Copper (Cu), Manganese (Mn), Zinc (Zn), metals like Cobalt (Co), Magnesium (Mg), Nickel (Ni), Lead (Pb) are not detected from the samples in trace amount. The negative contaminations of the heavy metals on the Red Sea made a huge impact on coral reefs ecosystem due to the release of sewage or STP water released to the Red Sea (Ali et al., 2011). Substantial modification in the electrical conductivity implies the water quality (Kinuthia et al., 2020). In a similar study conducted in wastewater outlet of Bilaspur, India, shows 1460.32 μS/cm, which is due to an excess amount of food-grade salt content in the wastewater due to a lot of hotels kitchen waste releases wastewater to sewage system (Ma et al., 2020). The mean electrical conductivity in spot A is higher than in spot B and C. This is because Jazan city is a populated urban area that outlets a large volume of household and restaurant waters. This resulted in an increased conductivity value crossing the WHO guideline value of 1000 $\mu S/cm^{-3}$ for wastewater discharge into sewage (Patel and Puttiah, 2011).

5. Conclusion

This work is the initial investigation to study the heavy metals released towards the Red Sea from various STP from the Jazan region in Saudi Arabia. The results of this study could be used as a baseline for future studies in anthropogenic effects of heavy metals released to Red Sea.

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.

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