Asian Journal of Geological Research

Volume 7, Issue 1, Page 21-30, 2024; Article no.AJOGER.111773

Assessment of the Physicochemical Characteristic of Wastewater in Kushtia and Jhenaidah Municipal Areas Bangladesh: A Study of DO, BOD, COD, TDS and MPI

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/111773

Original Research Article

Received: 21/11/2023
Accepted: 26/01/2024
Published: 31/01/2024

ABSTRACT

Comparing the physicochemical properties, heavy metals concentration and metal pollution index (MPI) of collected ten (10) wastewater samples in Kushtia and Jhenaidah municipalities, Bangladesh is the prime object of this manuscript. The levels of dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total dissolved solids

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(TDS) in the Kushtia municipal area ranged from 0.21 to 1.24 mg/L; 63.67 to 134.66 mg/L; 97.33 to 592.34 mg/L and 431.34 to 849.33 mg/L respectively. In the Jhenaidah municipal area, the levels ranged from 0.34 to 1.72 mg/L; 45.67 to 125.34 mg/L; 55.33 to 491.67 mg/L and 412.34 to 895.66 mg/L respectively. Atomic absorption spectrophotometer (AAS) where an air-acetylene flame with a digital readout system in Varian Spectra AA220 was introduced. Air-acetylene flames that reach about 2300.0 °C were introduced to determine the concentrations of arsenic (As), cadmium (Cd), lead (Pb), zinc (Zn) and manganese (Mn). The results showed that the As, Cd and Zn levels in the surface sewerage wastewater were within the permissible limit except for Mn and Pb in the Kushtia municipal area. Similar results were discovered in the Jhenaidah municipal area. Due to the elevated levels of Mn and Pb, beyond the acceptable threshold in both communities, there is a substantial health hazard for inhabitants and aquatic creatures. In addition, metal pollution index (MPI) values were measured at the maximum of 0.034 at Mill Para in Kushtia whereas 0.018 for Borohat Park Para in Jhenaidah. The MPI values revealed that these two regions are riskier compared to others. The findings are significant and can potentially influence future policies and actions regarding wastewater management in the municipal area. The indication of moderate wastewater quality suggests that there may be room for improvement in the treatment and disposal processes before release to the environment. This investigation aims to contribute to sustainable urban development and environmental protection initiatives.

Keywords: Wastewater; physicochemical; heavy metals; AAS; metal pollution index.

1. INTRODUCTION

Wastewater refers to water used and containing dissolved or suspended solids. It is discharged from residential, commercial and industrial sources, including paint and pigment production, glass manufacturing, mining operations, metal plating, battery manufacturing, etc. Heavy metals can be produced by households and various industries such as mining, metal processing, cable manufacturing, and microchip production [1,2,3]. They can be washed with water which may include residual acids, metals from plating and hazardous compounds [4,5,6]. The use of wastewater to irrigate agricultural grounds is one of the frequent utilizations in sub-urban and industrial regions in various parts and organs of the planet [7,8,9]. Discharging municipal and industrial trash into the water sources produces severe concerns affecting the ecosystem and causing it damage [10,11]. If the effluents of businesses and others are polluted with hazardous metals, it can endanger human health with acute and chronic disorders [12,13]. Wastewater comprises considerable percentages quantities of dangerous heavy metals such as As, Zn, Mn, Cd and Pb [14,15] which frequently leads to the impairment of soil health and pollution of the food chain largely through the vegetables cultivated on such soils [16,17]. The poisonous heavy metals and their ions have not only the potential for human health damage but also other living forms and organs. Toxic heavy metal ions cause bodily irritation and possibly life-threatening diseases involving irreparable damage to the key body system [18,19]. These heavy metals present in wastewater are non-biodegradable and their presence in lakes and streams where they are discharged leads to the buildup of these metals in living organisms. The discharge of a substantial quantity of toxic metals into aquatic ecosystems gives rise to significant health and ecological concerns and can result in a costly expenditure for wastewater treatment [20, 21] and dye removal [22]. The primary objectives of the study were to examine various physicochemical parameters in the municipal wastewater of Kushtia and Jhenaidah municipal areas. Additionally, the investigation aimed to identify the presence of heavy metals and calculate the MPI values in the municipal wastewater of both areas. This analysis was conducted to determine the areas with higher risk and raise awareness about the contamination levels in these regions.

2. MATERIALS AND METHODS

2.1 Sampling Location

The study area was Chamra Potti (23^0 53´ 51.36˝ N and 89^0 7´ 5.46˝ E), Chourhas Moar (23^0 53´ 34˝ N and 89^0 6´ 42˝ E), Kataikhana Moar (23^0 32´ 14˝ N and 89^0 11´ 0.2˝ E), Mill para (23^0 32´ 14˝ N and 89^0 11´ 0.2˝ E), Housing D-Block (23^0 32´ 14˝ N and 89^0 11´ 0.2˝ E) at Kushtia in Bangladesh and Modern Para (23^0 32´ 14˝ N and 89^0 11´ 0.2˝ E), Borohat Park Para (23^0 33´ 10.15˝ N and 89^0 10´ 31.29˝ E), Bepari Para (23^0 32´ 32.54˝ N and 89^0 10´ 9.87˝ E), Pagla Kanai

(23^0 32΄ 25.74΄΄ N and 89^0 9΄ 51.65΄΄ E), Arabpur (23^0 33΄ 29.64΄΄ N and 89^0 10΄ 14.02΄΄ E) at Jhenidah in Bangladesh [15]. This location was chosen due to the deposition of municipal wastewater effluents on the dry land during the dry season in the Kushtia and the Jhenaidah districts. In the rainy season, the land becomes flooded, causing the toxic components of the effluents to be carried to nearby agricultural areas and water bodies. This can have detrimental effects on both humans and the environment. The study locations are shown in Fig. 1.

2.2 Physicochemical Parameters

2.2.1 Dissolved Oxygen (DO)

Dissolved oxygen (DO) refers to the quantity of oxygen gas (O_2) that is dissolved in a liquid solution. Dissolved oxygen (DO) is a crucial quantity in the analysis of water and wastewater. The association between it and the water body provides both direct and indirect insights into bacterial activity, photosynthesis, nutrition availability, stratification and other related factors [23]. The dissolved oxygen (DO) level falls as temperature rises but it increases with microbial activity [24,25]. The elevated dissolved oxygen (DO) levels during summer can be attributed to the rise in temperature as well as the extended period of intense sunshine which directly impacts the proportion of soluble gases such as oxygen (O_2) and carbon dioxide (CO_2). DO in the wastewater sample is evaluated titre-metrically by Winkler's technique after 5.0 days of incubation at 293.0 K temperature. The difference in initial DO and final DO shows the amount of oxygen the bacterium used during this period. This process requires specific BOD bottles which isolate the inner environment from ambient oxygen.

2.2.2 Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD) measures how much dissolved oxygen is required for aerobic living organisms to decompose organic matter in a particular water sample.

It is expressed in mg/L. BOD was estimated by following the equation [24,19].

$$BOD = (D_0-D_5)/P \quad (1)$$

Where D_0=Dissolved oxygen of the diluted solution after preparation(mg/L), D_5 = D_0 of the diluted solution after 5.0 days incubation (mg/L), P = Decimal dilution factor.

2.2.3 Chemical Oxygen Demand (COD)

Chemical Oxygen Demand (COD) may be described as the amount of oxygen necessary to consume in the oxidation of organic molecules by powerful oxidizing agents such as dichromate or permanganate, thereby reflecting the organic content in the water sample. The measurement of COD occurred with the closed reflux technique in which outcomes were acquired in 3.0 to 4.0 hours. In 15.0 ml COD digestion tubes (prewashed with dilute H_2SO_4) 0.50 ml wastewater sample (inlet) or 1.00 ml treated sample was obtained. Next, a 2.50 ml portion of the standard potassium dichromate digestion reagent was gradually introduced and properly blended. In addition, 3.50 ml of sulfuric acid was introduced into the tubes and left to sediment at the base. The contents were sealed and agitated (use protective hands since the contents are highly heated) and then cooled. Once more, the transfer tubes within the pre-heated COD were subjected to digestion at a temperature of 150.0 °C for 2.0 hours. Three blanks were introduced by replacing the sample with drinking water and the procedure was carried out in the same manner as with the sample. The contents of the COD digestion tube were transferred to a 100.00 ml beaker for titration. To get the volume up to 50.0 ml distilled water was then added. Titration was performed using a 0.05 M ferrous ammonium sulfate (FAS) solution after adding 1.0 to 2.0 drops of Ferroin indicator [25].

$$\text{COD as mg } O_2/L = \{(A-B \times M \times 8000\}/\text{Volume of Sample (in ml)} \quad (2)$$

Where A = ml ferrous ammonium sulfate (FAS) solution is used for blank; B= ml ferrous ammonium sulfate (FAS) solution is used for sample and M= molarity of ferrous ammonium sulfate (FAS) solution.

2.2.4 Total Dissolves Solids (TDS)

Total solids in wastewater include both suspended and dissolved solids. Sedimentation is a method for removing settleable solids. The settling-able solids are measured in mg/L or ppm units. Usually, roughly 60.0 % of the suspended particles in industrial wastewater are settleable. To conduct this test, the volume of solids in 1.0 L of the sample was measured. This sample was meant to settle to the bottom of a conical flask during the subsequent evaporation process and dry in an oven at a precise temperature of 103 to 105.0 °C.

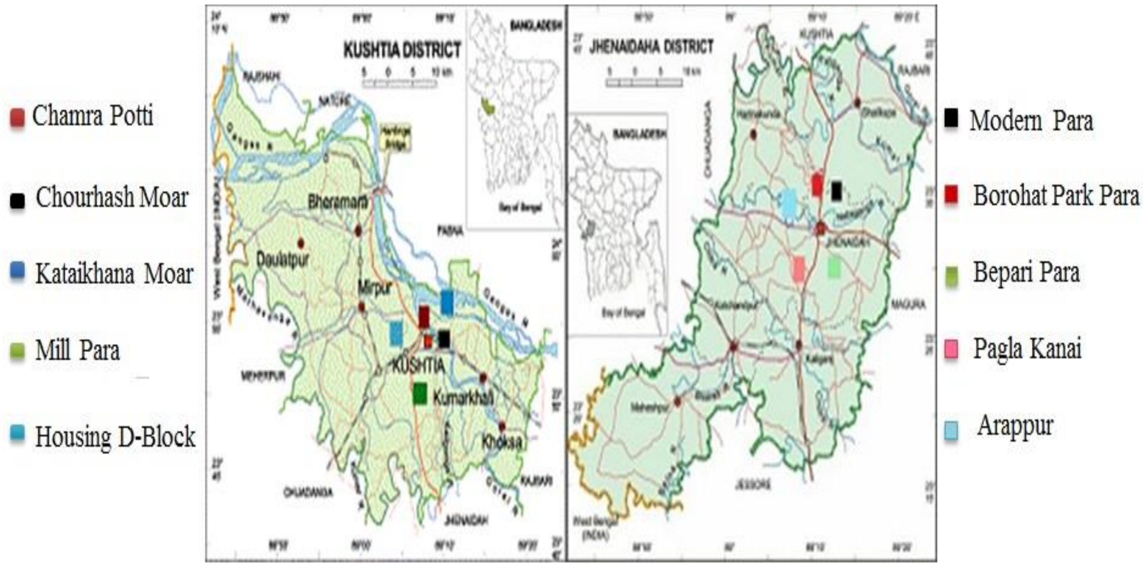

Fig. 1. Sampling location of Kushtia and Jhenidah districts

2.3 Heavy Metals Determination

2.3.1 Samples digestion for heavy metals

Five (05) sampling points in Kushtia municipal area were sampled using acid-washed polyethene bottles (Chamra Potti, Chourhash moar, Kataikhana moar, Mill Para, Housing D-block) and five (5) sampling points in Jhenaidah municipal area (Modern Para, Borohat Park Para, Bepari Para, Pagla Kanai, Arappur) were sampled. To remove unwanted particles, use filter paper Whatman 541. To minimize metal absorption into the container walls, 2.0 ml ultrapure HNO_3, 5.0 ml HCl and 2.50 ml of concentrated H_2SO_4 were added per litre of water sample [26].

2.3.2 Analysis of heavy metals by AAS

Heavy metal concentrations (Zn, Pb, Cd, As, Mn) in wastewater were measured using an air-acetylene flame with a digital readout system for AAS by Varian Spectra AA220, Australia. Air-acetylene flames reach about 2300.0 °C while acetylene-nitrous oxide flames reach around 3000.0 °C [27]. Typically, the presence of cadmium, lead and zinc can be detected using an air-acetylene flame. The samples must either be in a solution form or undergo digestion to be detectable by Flame Atomic Absorption Spectroscopy (FAAS). The typical detection limits vary from milligrams per litre (mg/L) to parts per million (ppm) and the sample analysis for each element takes around 10.0 to 15.0 seconds. Typically, hollow cathode lamps were employed as the source either a flame or a graphite furnace served as the atomizer, a grating was utilized as the wavelength selector and a photomultiplier functioned as the detector. Previous studies have documented the analytical requirements for quantifying heavy metals in water solutions using Atomic Absorption Spectroscopy (AAS). The certified and observed values exhibited a strong agreement [28,29].

2.4 Metal Pollution Index (MPI)

To assess the concentration of heavy metals in the wastewater sample at various sampling locations, the Metal Pollution Index (MPI) was determined using this equation [30].

$$MPI = (Cf_1 \times Cf_2 \times Cf_3 \times Cf_4 \times Cf_5 \times \text{----} \times Cf_n)^{1/n} \quad (3)$$

Where "Cf_1" = Concentration of heavy metals in the wastewater sample and "n" = Total number of heavy metals in that sample.

3. RESULTS AND DISCUSSION

3.1 Wastewater Parameters (DO, BOD, COD and TDS)

This investigation found that the levels of dissolved oxygen (DO), biochemical oxygen demand (BOD) and chemical oxygen demand (COD) in wastewater samples from the Kushtia municipal area ranged from 0.21 to 1.24 mg/L, 63.67 to 134.66 mg/L and 97.33 to 592.34 mg/L, respectively. In the Jhenaidah municipal area, the levels of DO, BOD and COD in wastewater samples ranged from 0.34 to 1.72 mg/L, 45.67 to 125.34 mg/L and 55.33 to 491.67 mg/L, respectively. In every case, the values were well below the permissible limit of DO value in wastewater 4.5 to 8.0 mg/L [31]. At a low level of DO value, marine animals cannot survive. Here, comparing both municipal areas, the DO values at Chourhas Moar (0.21 mg/L) were the lowest whereas at Mill Para (1.24 mg/L) were the highest in the Kushtia municipal area. In contrast, 0.34 mg/L was at Modern Para as the lowest value whereas Arappur (1.72 mg/L) was the highest one in the Jhenaidah municipal area. A high BOD value suggests a high quantity of easily degradable, organic material in the sample. A low BOD value signifies a small quantity of organic compounds which are resistant to decomposition or may be affected by measurement issues. The acceptable threshold for Biochemical Oxygen Demand (BOD) in inland surface wastewater is 30.0 mg/L [31,19] and 50.0 mg/L [32]. In both municipal regions, BOD concentrations were greater than the allowable limit.

In contrast, the acceptable limit for COD is 250.0 to 500.0 mg/L (WHO, 2010) and 200.0 mg/L (ECR, 1997) for inland surface wastewater. At Chamra Potti in the Kushtia, the COD value (592.34 mg/L) and COD value (491.67mg/L) were the highest at Pagla Kanai in the Jhenaidah means the quality of surface water is very detrimental in those places. Indian Standards Institution (ISI) acceptable maximum for BOD is 100.0 mg/L [33] and 50.0 mg/L [32] for inland surface wastewater. In both municipal regions, BOD concentrations were greater than the allowable limit. In contrast, The Indian Standards Institution (ISI) permissible limit for COD is 250.0 mg/L [33,32] for inland surface wastewater. At Chamra Potti in Kushtia, the COD value (592.34 mg/L) and COD value (491.67mg/L) were the highest at Pagla Kanai in Jhenaidah means the quality of surface water is very detrimental in those places. The TDS values at Housing D-Block (431.34 mg/L) were the lowest whereas at Kataikhana Moar (849.33 mg/L) were the highest in the Kushtia municipal area. In contrast, 412.34 mg/L was at Arappur as the lowest value whereas Borohat Parkpara (895.66 mg/L) was the highest one in Jhenaidah municipal area. Guideline values for TDS in drinking water recommended by WHO were less than 1,000.00 mg/l [34] as well as the nanomaterials have an outstanding significance [35, 36, 37,38] in this inhabitation control and cyanobacteria, vegetable and phytochemicals also responsible for controlling the purification of trace and heavy metals [39, 40, 41, 42].

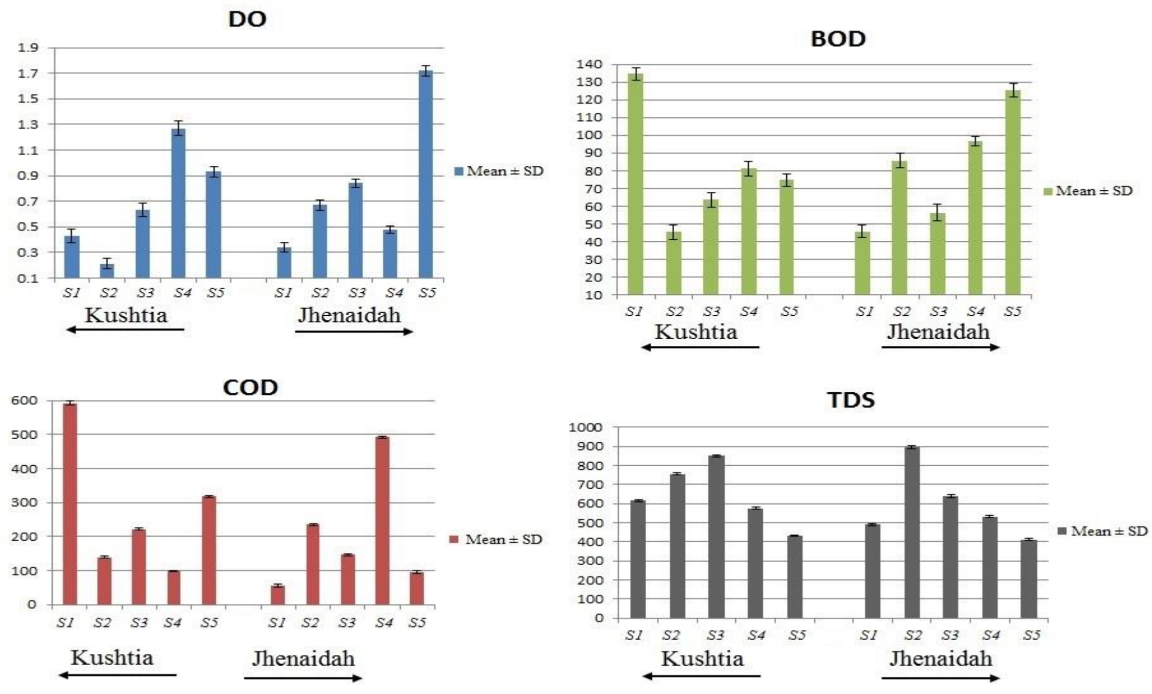

Fig. 2. The wastewater parameters of the municipal area in comparison between Kushtia and Jhenaidah municipal areas in Bangladesh

Table 1. The level of heavy metal content in the wastewater of the Kushtia municipal area

Sample No.	Sampling Location	Heavy metal concentration (mg/L)					
		As[a] LOQ:0.0007	Mn[a] LOQ:0.001	Pb[a] LOQ:0.001	Cd[a] LOQ:0.0005	Zn[a] LOQ:0.005	References
S-1	Chamra Potti	0.004±0.002	0.829±0.004	0.086±0.002	<LOQ	0.078±0.002	OS[b]
S-2	Chourhash Moar	0.007±0.002	0.383±0.011	0.056±0.003	<LOQ	0.008±0.001	OS[b]
S-3	Kataikhana Moar	0.012±0.009	0.516±0.004	0.067±0.002	<LOQ	0.071±0.002	OS[b]
S-4	Mill Para	0.017±0.002	0.784±0.008	0.076±0.002	<LOQ	0.091±0.003	OS[b]
S-5	Housing D-Block	0.006±0.002	0.486±0.008	0.048±0.002	<LOQ	0.102±0.007	OS[b]
SSW	-	0.05	0.05	0.05	0.05	5.0	ECR, [25]
GW	-	0.01	0.2	0.05	0.01	2.0	WHO ,[24]

[a] (Mean ± SD); LOQ = limit of quantification; [b] OS = Our study; SSW= Surface sewerage wastewater, GW=Ground Water

Table 2. The level of heavy metal content in the wastewater of the Jhenaidah municipal area

Sample No.	Sampling Location	Heavy metal concentration (mg/L)					
		As[a] LOQ:0.0007	Mn[a] LOQ:0.001	Pb[a] LOQ:0.001	Cd[a] LOQ:0.005	Zn[a] LOQ:0.005	References
S-1	Modern Para	0.005±0.004	0.255±0.004	0.065±0.003	<LOQ	0.021± 0.003	OS[b]
S-2	Borohat Park Para	0.036±0.025	0.551±0.003	0.046±0.004	<LOQ	0.053±0.004	OS[b]
S-3	Bepari Para	0.004±0.002	0.583±0.004	0.072±0.002	<LOQ	0.007±0.003	OS[b]
S-4	Pagla Kanai	0.007±0.002	0.479±0.002	0.036±0.002	<LOQ	0.028±0.003	OS[b]
S-5	Arap-pur	0.003±0.002	0.324±0.003	0.061±0.002	<LOQ	0.0713±0.002	OS[b]
SSW	-	0.05	0.5	0.05	0.05	5.0	ECR, [25]
GW	-	0.01	0.2	0.05	0.01	2.0	WHO, [24]

[a] (Mean ± SD); LOQ = limit of quantification; [b] OS = Our study; SSW= Surface sewerage wastewater. GW=Ground Water

Table 3. The value of the Metal Pollution Index (MPI) of various locations of Kashia and Jhenaidah Municipal area

Metal Pollution Index (MPI)	**Location of Kushtia Municipal Area**				
	Chamra Potti	Chourhash Moar	Kataikhana Moar	Mill Para	Housing D-block
	0.025	0.014	0.021	0.034	0.015
	Location of Jhenaidah Municipal Area				
	Modern Para	Borohat Park Para	Bepari Para	Pagla Kanai	Arap-pur
	0.015	0.018	0.014	0.017	0.015

3.2 Heavy Metals Analysis

The wastewater samples contain heavy metals, with their respective concentrations (measured in mg/L), listed in Table 1 and Table 2. Variations in the amounts of heavy metals in different wastewater samples can be attributed to the differing capacities of these samples to absorb and accumulate such metals [43]. The average concentration of heavy metals in diverse zones followed the ranking order: Mn > Pb > Zn > As > Cd. Among all the wastewater samples manganese (Mn) contains the highest average concentration and cadmium (Cd) contains the lowest. The wastewater sample shows an appreciable concentration of heavy metals varying from 0.002 to 0.015 mg/L and 0.373 to 0.826 mg/L, 0.046 to 0.084 mg/L, indicated limit of quantification levels and 0.0085 to 0.096 mg/L for arsenic (As), manganese (Mn), lead (Pb), cadmium (Cd) and zinc (Zn) respectively of Kushtia municipal area and 0.007 to 0.01 mg/L and 0.251 to 0.587 mg/L, 0.034 to 0.069 mg/L, was indicated limit of quantification level and 0.007 to 0.048 mg/L for As, Mn, Pb, Cd, and Zn respectively of Jhenaidah municipal area. All the wastewater samples contain the highest manganese (Mn) concentration. The wastewater samples contain a higher number of heavy metals than the permissible limit [44] Among the wastewater samples the highest amount of Mn (0.373 to 0.826 mg/L) was in the Kushtia municipal area and Mn (0.251 to 0.587 mg/L) in the Jhenaidah municipal area which is several times higher than the [44] permissible limit (0.2 mg/L) and it contributed a high risk of a human being (how it contributes risks to human and environment). Lead (Pb) is in the second position in concentration in wastewater samples.

The concentration ranges from 0.046 to 0.084 mg/L in the Kushtia municipal area and 0.034 to 0.069 mg/L in the Jhenaidah municipal area which is higher than the [32] and [44] permissible limit (0.50 mg/L) and it posed a significant threat to both human beings and the environment. The wastewater samples from Kushtia included a concentration of zinc (Zn)b ranging from 0.0085 to 0.096 mg/L, whereas the samples from Jhenaidah had a concentration of zinc (Zn) ranging from 0.007 to 0.048 mg/L. These concentrations are below the permitted limits stated in references [32] and [44]. The cd was detected in the limit of quantification level which is lower than the [32] and [44] permissible limit (0.1 to 0.05 mg/L) shown in Table 1 and Table 2. The concentration of the examined wastewater samples varies from 0.002 to 0.015 mg/L in Kushtia and from 0.007 to 0.01 mg/L in Jhenaidah, all of which fall within the safe limit of 0.1 mg/L.

3.3 Metal Pollution Index (MPI)

The presence of heavy metal contamination in wastewater was determined by calculating the MPI using equation 3. MPI values were detected as 0.025, 0.014, 0.021, 0.034 and 0.015 for Chamra Potti, Chourhas Moar, Kataikhana Moar, Mill Para and Housing D-Block locations in Kushtia municipal area respectively and 0.015, 0.018, 0.014, 0.017 and 0.015 for Modern Para, Borohat Park Para, Bepary Para, Pagla Kanai and Arappur location in Jhenaidah municipal area respectively.

The MPI offers data on the overall pollution status of different locations within the Kushtia and Jhenaidah municipal regions. The MPI values for the different locations were computed and are presented in Table 3. Among the different locations, the highest MPI values were found in mill para and lowest by Chourhas Moar of the Kushtia municipal area and the highest MPI values were found in Borohat Park para and lowest in modern para and Arappur of the Jhenaidah municipal area. The increasing order of risk zones Chourhas Moar < Kataikhana Moar < Housing D-Block < Chamra Potti < Mill Para of Kushtia municipal area and Bepary < Para Modern Para and Arappur < Pagla Kanai < Borohat Park Para of Jhenaidah municipal area.

4. CONCLUSIONS

The primary objective of this study endeavor was to ascertain the levels of several hazardous heavy metals (Arsenic, Manganese, Lead, Cadmium, and Zinc) as well as certain physicochemical characteristics including Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Dissolved Solids (TDS). The experimental results indicated that the dissolved oxygen (DO) and total dissolved solids (TDS) levels in all wastewater samples were below the acceptable thresholds established by the World Health Organization (WHO) and the Indian Standards Institute (ISI). However, the biochemical oxygen demand (BOD) and chemical oxygen demand (COD) levels were found to exceed the allowed limitations set by WHO and the Environmental Control Regulations (ECR). The BOD and COD measurements suggest a progressive rise in contamination levels. Even so, the wastewater samples contained excessive amounts of Mn and Pb, surpassing the limits established by WHO. This poses a significant health risk to the residents in the study region, as well as to the aquatic ecosystem and the water-receiving areas of the locality. The levels of As and Cd were found to be within the standard limits set by WHO and ECR. Heavy metal concentrations in the wastewater would increase by increasing population and their activities developments in the study region. Higher concentrations of heavy metal ions in wastewater are directly falling into nearby Ponds, Khalsa, Beels, Rivers, Drains, Canals and others that ultimately affect the physiological function of plants and also affect to function of biological compounds. If appropriate measures are not implemented, the contamination in aquatic systems will progressively escalate. Hence, it is imperative to implement appropriate measures and rigorous surveillance to uphold the ecosystem in its pristine condition. This investigation recommended further development and the necessary steps to take before discharging this wastewater into the nearby Ponds, Khalsa, Beels, Rivers, Drains, Canals, agricultural fields and others.

ACKNOWLEDGEMENTS

The authors express their heartiest thanks to the Chairman, Department of Applied Chemistry and Chemical Engineering (ACCE), Islamic University, Kushtia-7003, Bangladesh and the Division in charge, IPCRD, IGCRT, BCSIR for a permit to access the software, appliance and computers. The research work was funded by the Faculty of Applied Science and Technology, Islamic University, Kushtia-7003, Bangladesh.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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