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*Research article*

# Impact of sugar mills effluent on environment around mills area

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**Abstract:** The discharge of untreated industrial effluents degraded water and soil, and the entire environment. The study aimed to evaluate the impacts of sugar mills effluent on the environment around the mills' area. A total of 120 effluents, soils, and water samples were collected three times a year over two years to analyze the physicochemical parameters. A field survey also was conducted on two hundred households of fourteen villages of the two Upazila in Joypurhat District of Bangladesh. The survey observed that majority of the people have negative opinions regarding the impacts of sugar mills effluents on fish, crops, and human health life. The higher BOD5 level in the effluents indicated that the decline in DO that the bacteria consumed the available oxygen in the water leading to the inability of fish and other aquatic organisms to survive in the water body. The study observed that the concentrations of $Fe^{3+}$, $Mn^{2+}$, and $Pb^{2+}$ were found higher than the standard permissible limit of DoE-BD (2003) indicating the severe environmental degradation occurred in the areas. The study observed that the surface water, groundwater, and soil were contaminated through the discharge of sugar mills untreated effluents severely degraded the environment of the areas.

**Keywords:** effluent; groundwater; harmful; surface water; soil; toxic

## 1. Introduction

Rapid industrialization brings pollutants into the environment that severely degraded the hydrosphere and atmosphere. The discharge of untreated industrial and domestic wastewater into the environment affects both soil and water quality. The disposal of industrial effluent is one of the most serious challenges all over the world as well as in Bangladesh [1]. Presently, only about 10% of industrial wastewater is being treated and the remaining portion is discharged into nearby water bodies [2,3]. The waste stream contains a complex mixture of toxic substances, predominantly natural and synthetic organic substances, including metals, trace elements, pathogens from domestic and industrial sectors that enters into streams, rivers, and other water bodies. The dissolved and suspended substances are deposited on the bed resulted in the degradation of water quality [4–6]. The severity of environmental degradation depends on the quality and quantity of discharge effluents into the soils and water bodies [7,8].

The most important effluent discharging industries are sugar mills, thermal power plants, paper mills textiles, distilleries, fertilizer units, electroplating plants, tannery industries, sago factories, oil refineries, pesticide, and herbicide industries. These industrial effluents containing heavy metals pose a serious threat to the ecosystem [9]. Brazil is at the top in the production of cane sugar countries followed by China, India, Thailand, Pakistan, and Mexico [10]. A large quantity of water is during the sugar manufacturing processes, and as a result, sugar mills discharge a large amount of wastewater. The discharged effluents were mixed with different chemicals used during processing [11]. Bangladesh produces 137000 metric tons annually and ranked 67th position among 130 sugar-producing countries [12]. There are 17 sugar mills in Bangladesh; most of them were established in rural areas. Joypurhat sugar mill is one of them. The Mills discharged untreated effluent is polluting the Tulshigongga River water. The environmental activists and some eco-friendly organizations have protested against river water pollution in the district. During the sugar harvest period, 10 sugar mills of the country discharge about 21405 cubic meter of wastewater daily. The rivers in Northern Bangladesh are polluting through the discharge of untreated industrial effluents, including the Padma, Soto Jamuna, Karatoa, Shok, Tanggon, Bengali, Tulshigongga, Narod, and Esamoti, rivers, and their tributaries. The wastewater of Joypurhat Sugar Mills Ltd is considered to be harmful to the fishes of about 75 km of canal and river areas. The effluents of the sugar industry in the area were discharged through small open drains into the main drain and were eventually fallen into the Shree River. They produce sugar as well as large amounts of wastewater. The sugar mills, on average, generate one cubic meter of wastewater per ton of crushed cane. The discharge of sugar mill's wastewater into the surface water bodies with a high TDS adversely affects aquatic life. The irrigation water for most of the Rabi-crop received unsuitable water during the sugar production period in November- April around the sugar mill areas [13]. Human life is also affected by the awful effects of untreated sugar industrial effluents [14].

Researchers are closely monitoring the consequences of discharging the waste from the industries and looking for innovative solutions to the challenging problems. A complex mixture of harmful chemicals, both organic and inorganic, is discharged into the water bodies from the sugar mills generally without any treatment threatened the entire environment. Thus the study aimed to assess the impacts of untreated sugar mills effluents on soil, water, and human life. The specific objectives of the study were to (i) understand people perceptions of the impacts of untreated effluents, (ii) identify the pollutants in the discharge effluents, (iii) identify the pollutants and assess their fates and effects on the soil, surface water, and groundwater around the sugar mills areas.

## 2. Materials and methods

### *2.1. Study area*

Joypurhat is a small district town in the northern part of Bangladesh with an area of 965.44 sq km. There are five Upazilas (administrative area) in this district. It is located at 25.100 °N–25°06′N and 89.033 °E– 89°02′E. There are 17 sugar mills industries in Bangladesh, and the Joypurhat sugar mill is one of them. Generally, industrial factories should set up in a distant place from an urban area. But Joypurhat sugar mills Ltd is attached with the Joypurhat town. Its daily sugarcane crashing power is 2032 mT (metric ton), and yearly sugar product power is 20320 mT. The untreated wastewater of the sugar mills is passing, through a tiled and non-tiled open drain. It passes through several villages and finally, falls into the Shree River. The study area map is shown in Figure 1.

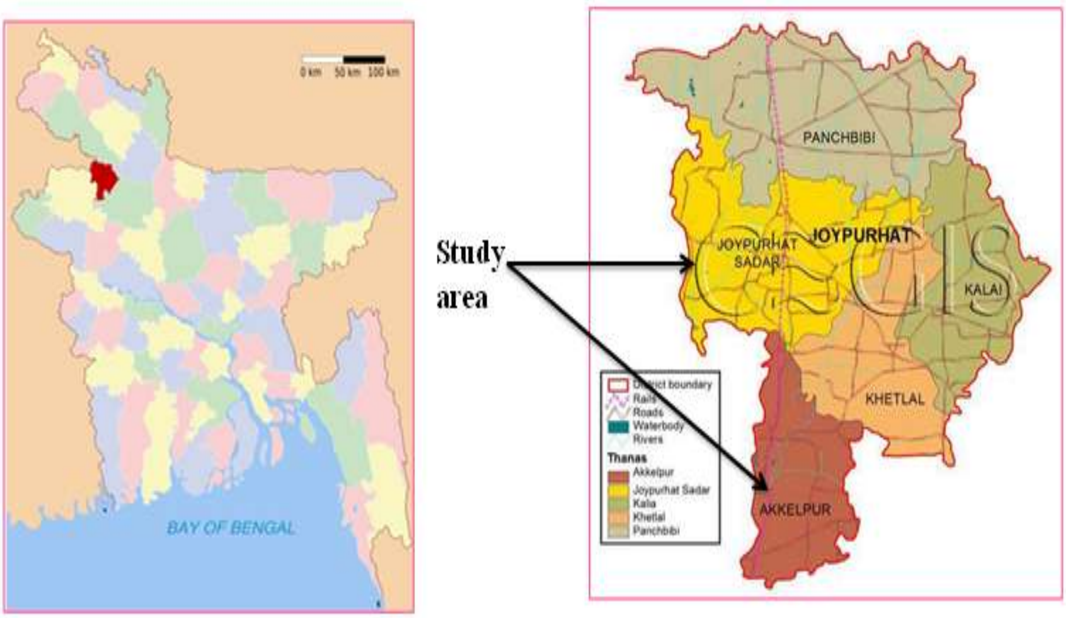


**Figure 1.** Map of the study area, Joypurhat, and Akkelpur Upazilas of Bangladesh.

### *2.2. Questionnaire survey*

An extensive field survey was conducted to get public opinions and understand the present scenarios of discharging untreated effluents of the Joypurhat sugar mills in the District. Two hundred households in fourteen villages along the effluent discharged drain of Joypurhat Sadar and Akkelpur Upazilas, were participated in the survey. The questionnaire survey was conducted based on 36 questions on different categories, including education status, family member, sanitary condition, household fuel and electricity consumption, drinking water source, drainage pattern, crops, fish, and human diseases. The data were collected as precisely as possible from the survey and analyzed using statistical methods of analysis.

*2.3. Sample collection*

Four types of samples, i.e., effluent, surface water, groundwater, and soil were collected from two Upazilas (administrative areas), i.e., Joypurhat Sadar and Akkelpur to analyze physicochemical parameters. A total of 120 samples, including effluents, surface water, groundwater, and soil were collected three times a year (pre-production period, production period, and post-production period) for two years. The samples were collected from five different location points identified as L-1 to L-5. The first location point (L-1) was the outlet of the sugar mills and the second (L-2) to fifth (L-5) location points were selected at a distance of 2, 5, 10, 15 km, respectively from the outlet of sugar mills.
It was the head-end of the effluent discharging drain that fell into the Sree River. The major physicochemical parameters, including EC, DO, pH, $BOD_5$, COD, $Na^+$, $K^+$, $Ca^{2+}$, $Fe^{3+}$, $Zn^{2+}$, $Mn^{2+}$, $Cd^{2+}$, $Pb^{2+}$, $Cl^–$, $NO_3^–$, $SO_4^{2–}$, and $PO_4^{3–}$ were considered in the study. A field survey was conducted on two hundred households of fourteen villages beside the effluent discharging drain passed through Joypurhat Sadar and Akklepur Upazila. The collected samples were characterized using standard methods of analysis and the experimental results were compared with the standards of wastewater (effluent), inland surface water, groundwater, and soil quality parameters which are the control variable that already exists.

*2.4. Sample preparation*

All the collected samples, i.e., effluent, surface water, groundwater, and soil were analyzed using the standard methods stated in American Public Health Association [15].

2.4.1. Effluent, surface water, and groundwater analysis

The study considered the parameters, including physio-chemical, cations, and anions for the effluents, surface water, and groundwater. The physio-chemical, parameters, including EC, DO, pH, BOD5, and COD; the major cations, including $Na^+$, $K^+$, $Ca^{2+}$, $Fe^{3+}$, $Mn^{2+}$, $Cu^{2+}$, $Cd^{2+}$, $Zn^{2+}$, and $Pb^{2+}$; and the anions, including $Cl^–$, $NO_3^–$, $SO_4^{2–}$, and $PO_4^{3–}$ were determined using the standard methods of analysis [15].

2.4.2. Soil analysis

Soil samples were collected from the same selected location points as discussed above. The collected soil samples were transported to the laboratory of the Bangladesh Council of Scientific and Industrial Research (BCSIR) in Joypurhat for chemical analyses using the XRF instrument (ZSX Primus, Rigaku Corporation). The soil samples were mixed with the analytical grade organic binder (stearic acid), placed inside plastic rings, and pressed to form discs. These discs were placed in the XRF instrument (ZSX Primus) for the characterization of the soil sample. The soil samples were dried in an oven at 40 ℃ until a constant weight was obtained. This was done to drive away from the moisture which was harmful to the XRF instrument. The samples were mixed with the analytical grade organic binder (stearic acid), placed inside plastic rings, and pressed to form discs. These discs were placed in the XRF instrument (ZSX Primus, Rigaku Corporation) and scanned X-Ray diffraction with Cu Kα radiation using the proprietary EZ Scan software.

## 3. Results and discussion

The impacts of discharging the untreated sugar mills effluents on the environment were analyzed for various physicochemical parameters of the effluents, water, and soil, and the results are discussed here.

### *3.1. Public perception survey*

Most of the people in the study have given their negative opinions regarding the impacts of sugar mills effluents on fish, crops, and human health life. They believed that the untreated effluents contained huge pollutants, which polluted the soil, waters, and human life around the sugar mills and effluent discharged drain adjacent areas. The survey report showed that the fish production in ponds, canals, and rivers was decreased about 67–73, 93–95, and 50–55%, respectively in the study areas due to the discharge of untreated effluents from the sugar mills (Table 1). Concerning the production of the crops, including rice, potatoes decreased to some extent. However, the production of some crops such as maize and sugarcane increased by 60 and 75%, respectively, due to the discharge of untreated sugar mills effluents (not shown in Table). The survey report also showed that about 21 and 18 % of respondents in Joypurhat Sadar and Akkelpur Upazila areas, respectively, were infected with skin diseases (Table 1).

**Table 1.** Field survey responses to agricultural production and human health.

| Area/Upazila | Fish production decreased (%) | | | Crop production decrease (%) | | Skin diseases (%) | Human health effect (%) |
|---|---|---|---|---|---|---|---|
| | Pond | Canal | River | Rice | Potato | | |
| Joypurhat | 67 | 95 | 21 | 75 | 92 | 21 | 80 |
| Akkelpur | 73 | 93 | 18 | 69 | 84 | 18 | 69 |

### *3.2. Physicochemical parameters*

The mean value of EC of the effluent, surface water, groundwater, and soil in the study varied from 488 to 1193 μS/cm (Table 2). The highest value was 1412 μS/cm found in the effluent samples indicating that the effluent contained high amounts of ions (not shown in Table 2). The higher EC values indicated the presence of huge amounts of ions of the effluents run into surface water and soil and ultimately polluted the surrounding environment.

The mean value of DO of the effluent, surface water, and groundwater in the areas was 0.48 to 8.74 mg/L, respectively (Table 2). The results showed that the DO of the surface water and groundwater were within the standard permissible limits [16–18]. However, the effluents' mean DO levels were below 1.5 indicated severe condition. When DO concentration is less than four (4) mg/L, aquatic animals are required to adjust their inhalation patterns and lower their level of activity. As the DO concentrations in the effluent were found to be very low, so it could have effects on the entire environment.

The pH is one of the most important operational quality parameters of water [19] and wastewater [20]. The observed pH values were within the range of the DoE-BD standard value. The pH of the effluent, surface water, and groundwater in the study areas was varied from 3.9 to 7.9 (not shown in Table 2). The observed pH values were found within the range of the DoE-BD (2003) standard [18].

The concentrations of $BOD_5$ and COD in all samples were found to be higher than the IS-2000, NEQS-2000, and DoE-BD 2003 standard limits. The higher $BOD_5$ values indicated the presence of high amounts of organic substances load in the effluents, which caused toxic effects on aquatic biota. Under such a condition, no aquatic life can survive, except for the anaerobic micro-organisms [21]. A similar observation made by Saifi et al. (2011) supported the present finding [22].

The mean $BOD_5$ in the effluent and surface water was varied from 5.05 to 209 mg/L (Table 2). The higher BOD5 level in the effluents indicated the aerobic bacteria consumed the available oxygen in the water, which led to a decrease in fish and other aquatic organisms in water bodies. The mean COD in the effluent and surface water in the study was varied between 6.9 to 440 mg/L (Table 2). The COD is an important indicator of deterioration of the water quality from discharging the untreated industrial effluent.

**Table 2.** Mean values and standard deviations of physicochemical parameters in the effluent, surface water and groundwater from Oct. 2014 (Pre-production) - Apr. 2016 (Post-production) at different locations.

| Parameters | Sample location | Effluent (Mean ±SD) | Surface water (Mean ±SD) | Groundwater (Mean ±SD) |
|---|---|---|---|---|
| EC (µS/cm) | L-1 | 1193 ±266 | 788 ±107 | 550 ±256 |
| | L-2 | 1183 ±273 | 778 ±103 | 521 ±240 |
| | L-3 | 1125 ±296 | 771 ±102 | 507 ±234 |
| | L-4 | 1110 ±291 | 767 ±103 | 493 ±222 |
| | L5 | 1079 ±286 | 761 ±104 | 488 ±218 |
| DO (mg/L) | L-1 | 0.48 ±0.23 | 6.3 ±1.86 | 8.74 ±0.23 |
| | L-2 | 0.68 ±0.32 | 6.17 ±1.92 | 8.67 ±0.23 |
| | L-3 | 1 ±0.39 | 6.16 ±1.91 | 8.60 ±0.3 |
| | L-4 | 1.3 ±0.13 | 6.11 ±1.9 | 8.56 ±0.34 |
| | L5 | 1.38 ±0.15 | 6.11 ±1.88 | 8.46 ±0.43 |
| pH | L-1 | 5.15 ±0.95 | 6.9 ±0.14 | 7.14 ±0.98 |
| | L-2 | 5.22 ±0.90 | 7.03 ±0.18 | 7.23 ±0.92 |
| | L-3 | 5.24 ±0.91 | 7.2 ±0.17 | 7.27 ±0.92 |
| | L-4 | 5.29 ±0.91 | 7.32 ±0.17 | 7.39 ±0.97 |
| | L5 | 5.34 ± 0.88 | 7.55 ±0.104 | 7.57 ±1.08 |
| $BOD_5$ (mg/L) | L-1 | 209 ±28.43 | 7.94 ±1.02 | 5.4 ±0.8 |
| | L-2 | 204 ±26.74 | 7.84 ±1.01 | 5.29 ±0.78 |
| | L-3 | 198 ±30.09 | 7.79 ±1.03 | 5.2 ±0.79 |
| | L-4 | 194 ±29.2 | 7.71 ±1.02 | 5.09 ±0.75 |
| | L5 | 186 ±31.19 | 7.68 ±1.0 | 5.05 ±0.75 |
| COD (mg/L) | L-1 | 440 ±93.91 | 8.14 ±1.35 | 7.16 ±1.22 |
| | L-2 | 434 ±93.48 | 8.02 ±1.32 | 7.09 ±1.22 |
| | L-3 | 417 ±84.48 | 7.93 ±1.3 | 7 ±1.22 |
| | L-4 | 407 ±79.67 | 7.83 ±1.28 | 6.96 ±1.23 |
| | L5 | 383 ±64.36 | 7.77 ±1.25 | 6.9 ±1.21 |

The results showed that the average COD values of all effluent samples at five locations were found highest during the production period. The huge amount of organic and inorganic substances discharged through the effluent during the crushing process may be the cause of increasing the COD values. The results showed that COD values in the sugar mills effluent were found higher than the tolerance limits for inland surface water. The results illustrated that the high COD values indicated the presence of the high organic load and inorganic chemicals in the effluents. Akan et al. (2007) also reported that the higher levels of BOD and COD in sugar mills effluent contained organic and inorganic substances may cause toxic conditions with consequent adverse effects on aquatic biota [23]. The higher concentrations of BOD and COD in all the samples indicated severe pollution of areas caused by the discharged effluent threatened the environment.

**Table 3.** Physicochemical parameters of effluents exceed the DoE-BD (2003) standard

| Parameters | No. of sample exceed DoE value | % of sample exceed DoE value | Concentration ranges from to | DoE standard value |
|---|---|---|---|---|
| EC(μS/cm) | 20 | 66.67 | 712–1412 | 1200 |
| DO (mg/L) | 30 | 100 | 0.2–1.6 | 4.5–8 |
| $BOD_5$ (mg/L) | 30 | 100.00 | 145–236 | 50 |
| COD(mg/L) | 30 | 100.00 | 297–508 | 200 |

**Table 4.** Major cations in effluent of Joypurhat Sugar Mills collected during Oct. 2014 (Pre-production) to Apr. 2016 (Post-production).

| Elements (mg/L) | Sample Location | Period | | | | | | Standard Permissible Limits | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Preproduction 2014 | Production 2015 | Postproduction 2015 | Preproduction 2015 | Production 2016 | Postproduction 2016 | IS-2000 | NEQS-2000 | DoE-BD |
| Na | L-1 | 0.426 | 0.687 | 0.528 | 0.431 | 0.689 | 0.536 | - | - | 200 |
| | L-2 | 0.418 | 0.656 | 0.519 | 0.421 | 0.674 | 0.525 | | | |
| | L-3 | 0.405 | 0.594 | 0.498 | 0.409 | 0.612 | 0.508 | | | |
| | L-4 | 0.394 | 0.575 | 0.496 | 0.398 | 0.588 | 0.498 | | | |
| | L-5 | 0.382 | 0.533 | 0.487 | 0.390 | 0.536 | 0.489 | | | |
| K | L-1 | 4.255 | 4.997 | 4.964 | 4.316 | 5.008 | 4.892 | - | - | 12 |
| | L-2 | 4.248 | 4.972 | 4.958 | 4.308 | 4.993 | 4.886 | | | |
| | L-3 | 4.230 | 4.928 | 4.917 | 4.298 | 4.972 | 4.874 | | | |
| | L-4 | 4.219 | 4.864 | 4.840 | 4.272 | 4.916 | 4.859 | | | |
| | L-5 | 4.211 | 4.785 | 4.753 | 4.254 | 4.894 | 4.843 | | | |
| Ca | L-1 | 27.99 | 38.13 | 37.98 | 28.12 | 39.31 | 38.75 | 200 | 200 | 75 |
| | L-2 | 27.88 | 38.12 | 37.86 | 27.91 | 39.27 | 38.63 | | | |
| | L-3 | 26.34 | 37.89 | 36.77 | 26.77 | 38.62 | 37.81 | | | |
| | L-4 | 25.87 | 36.73 | 35.61 | 26.21 | 37.54 | 36.32 | | | |
| | L-5 | 24.72 | 35.61 | 34.43 | 25.13 | 36.12 | 35.15 | | | |

Note: IS-2000: Indian Standard -2000; NEQS- 2000; National Environmental Quality Standard-2000; DoE: Department of Environment, Bangladesh, 1997.

Table 3 shows the percentage of samples that exceeded the DoE-BD standard limit. The study results illustrated that all the samples belong to the surface and groundwater for the physicochemical parameters were found within the DoE-BD permissible standard. However, the effluents for EC, Do, BOD, and COD were exceeded 66.67 to 100% samples indicating the discharged effluent might harm the environment around the sugar mills effluent discharged areas.

*3.3. Cationic parameters*

The metals have adverse effects on crop production due to the danger of bioaccumulation and bio-magnification in the food chain. There is also the threat of superficial and groundwater pollution. The fate and transfer of heavy metals in the soil were depended considerably on the chemical form and speciation of the metal [24]. Table 4 shows a detailed analysis of some major cations, i.e., $Na^{+}$, $K^{+}$, and $Ca^{2+}$ in the effluent samples. The concentration of the cations was found within the permissible standard of DoE-BD. The concentration of all cations of the effluent, surface, and groundwater was found higher in the production period than in the other two periods (not shown in Table 4). However, the concentration of these cations was found within the permissible limit recommended by the DoE-BD (2003) (not shown in Table).

According to Table 5, the most common heavy metals found in the effluents at Joypurhat Sadar and Akkelpur Upazila areas in the order of abundance are $Fe^{3+}$> $Mn^{2+}$> $Zn^{2+}$> $Cu^{2+}$> $Pb^{2+}$> $Cd^{2+}$. However, However, in the soil, the dominant cations followed the order as $Fe^{3+}$>$Mn^{2+}$> $Zn^{2+}$> $Pb^{2+}$>$Cu^{2+}$> $Cd^{2+}$. This distribution of heavy metals in soils was believed to be controlled by many ways such as mineral precipitation, dissolution, ion exchange, adsorption, and desorption, aqueous complication, biological immobilization, mobilization, and plant uptake [25]. The concentrations of Zn, Cu, and Cd in all samples were found below the permissible limit of IS-2000, NEQS-2000, and DoE-BD standards for discharged effluents.

The analysis results showed that the maximum concentrations of iron (Fe) in the effluent, surface water, groundwater were 13.1, 7.5, and 5.3 mg/L, respectively, found during the study period (Table 6). About 100% of samples exceeded the DoE-BD standard values of the effluents and groundwater samples, and about 67% of surface water samples exceeded the DoE-BD standard value for iron concentration (Table 6). Anaerobic groundwater may contain iron (II) at concentrations up to several milligrams per liter without discoloration or turbidity in the water when directly pumped from a well. Taste is not usually noticeable at iron concentrations below 0.3 mg/L, although turbidity and color may develop in piped systems at levels above 0.05–0.1 mg/L [26]. Laundry and sanitary ware stain at iron concentrations above 0.3 mg/L. Iron also promotes undesirable bacterial growth ("iron bacteria") within a waterworks and distribution system, resulting in the deposition of a slimy coating on the piping. The mean concentration of $Mn^{2+}$ in the effluent and surface water was found within the range of DoE-BD standard limits. But it exceeded the standard level in groundwater. The highest concentration of $Mn^{2+}$ was found to be 1.08 (Table 6).

**Table 5.** Mean and standard deviations of heavy metals in effluent, surface water groundwater and soil from Oct. 2014 (Pre-production) to Apr. 2016 (Post-production) at different locations.

| Cations (mg/L) | Sample location | Effluent (mg/L) Mean ±SD | Surface water (mg/L) Mean ±SD | Groundwater (mg/L) Mean ±SD | Soil (mg/kg) Mean ±SD |
|---|---|---|---|---|---|
| $Fe^{3+}$ | L-1 | 10.17 ±3.48 | 4.32 ±2.9 | 3.36 ±1.65 | 66.5 ±16.08 |
| | L-2 | 9.8 ±3.46 | 4.17 ±2.8 | 3.26 ±1.61 | 64.68 ±15.91 |
| | L-3 | 8.67 ±3.65 | 3.84 ±2.5 | 3.0 ±1.40 | 61.02 ±16.72 |
| | L-4 | 7.54 ±3.62 | 3.60 ±2.39 | 2.8 ±1.25 | 56.14 ±20.2 |
| | L-5 | 6.68 ±3.25 | 3.13 ±2.05 | 2.81 ±1.35 | 52.55 ±19.64 |
| $Mn^{2+}$ | L-1 | 1.74 ±0.9 | 1.48 ±0.46 | 0.92 ±0.17 | 5.16 ±1.67 |
| | L-2 | 1.71 ±0.89 | 1.45 ±0.45 | 0.83 ±0.18 | 4.99 ±1.72 |
| | L-3 | 1.66 ±0.86 | 1.35 ±0.4 | 0.76 ±0.24 | 4.54 ±1.49 |
| | L-4 | 1.64 ±0.84 | 1.18 ±0.3 | 0.7 ±0.21 | 4.12 ±1.36 |
| | L-5 | 1.61 ±0.83 | 1 ±0.17 | 0.68 ±0.2 | 3.6 ±1.11 |
| $Zn^{2+}$ | L-1 | 0.09 ±0.01 | 0.07 ±0.03 | 0.05 ±0.03 | 1.5 ±0.97 |
| | L-2 | 0.09 ±0.01 | 0.07 ±0.02 | 0.05 ±0.03 | 1.06 ±0.99 |
| | L-3 | 0.09 ±0.01 | 0.06 ±0.02 | 0.04 ±0.03 | 0.29 ±0.02 |
| | L-4 | 0.09 ±0.01 | 0.06 ±0.02 | 0.04 ±0.03 | 0.24 ±0.03 |
| | L-5 | 0.08 ±0.01 | 0.05 ±0.02 | 0.03 ±0.02 | 0.19 ±0.02 |
| $Cu^{2+}$ | L-1 | 0.08 ±0.02 | 0.11 ±0.056 | 0.004 ±0.001 | 0.141 ±0.014 |
| | L-2 | 0.08 ±0.02 | 0.097 ±0.056 | 0.004 ±0.001 | 0.116 ±0.005 |
| | L-3 | 0.07 ±0.02 | 0.09 ±0.052 | 0.003 ±0.001 | 0.098 ±0.01 |
| | L-4 | 0.06 ±0.01 | 0.081 ±0.048 | 0.003 ±0.001 | 0.087 ±0.004 |
| | L-5 | 0.05 ±0.005 | 0.068 ±0.046 | 0.003 ±0.001 | 0.076 ±0.006 |
| $Cd^{2+}$ | L-1 | 0.003 ±0.0005 | 0.004 ±0.002 | 0.003 ±0.0008 | ND |
| | L-2 | 0.002 ±0.0008 | 0.004 ±0.001 | 0.003 ±0.0005 | ND |
| | L-3 | 0.002 ±0.0009 | 0.003 ±0.001 | 0.003 ±0.0005 | ND |
| | L-4 | 0.002 ±0.0009 | 0.003 ±0.001 | 0.002 ±0.0005 | ND |
| | L-5 | 0.002 ±0.0009 | 0.002 ±0.0009 | 0.002 ±0.0008 | ND |
| $Pb^{2+}$ | L-1 | 0.147 ±0.007 | 0.072 ±0.031 | 0.065 ±0.03 | 0.45 ±0.32 |
| | L-2 | 0.146 ±0.003 | 0.070 ±0.031 | 0.063 ±0.03 | 0.44 ±0.31 |
| | L-3 | 0.140 ±0.004 | 0.070 ±0.031 | 0.061 ±0.03 | 0.42 ±0.31 |
| | L-4 | 0.139 ±0.0123 | 0.069 ±0.031 | 0.058 ±0.03 | 0.41 ±0.30 |
| | L-5 | 0.137 ±0.005 | 0.067 ±0.031 | 0.057 ±0.03 | 0.40 ±0.30 |

Note: *ND: Not detected

The mean value of Pb in the effluent, surface water, and groundwater samples in the areas was 0.069, 0.06, and 0.45 mg/L, respectively (Table 5). About 67% of the effluent samples exceeded the Pb concentration of the DoE-BD standard indicated possible human health effects (Table 6). One of the major mechanisms of Pb exerts the toxic effect is through biochemical processes that include the ability of Pb to inhibit or mimic the actions of calcium and interact with proteins [27]. Within the bones, Pb is integrated into the mineral in place of calcium. Lead ($Pb^{2+}$) binds to biological molecules and thereby intrusive with their utility by several mechanisms. Lead ($Pb^{2+}$) may also compete with necessary metallic cations for binding sites, inhibiting enzyme activity, or shifting the movement of essential cations such as calcium [27]. Lead ($Pb^{2+}$) can accumulate in the human body through the food chain and causes harmful effects on various human organs [2,9,28]. Besides, some of the toxic metal ions exceeded the standard permissible limits. These toxic metal ions and their compounds cause extremely harmful to human health through water and foodstuff. As the human consume the toxic metal ions, they may accumulate in bones and other organs. Thus, it causes diseases like diarrhea, carcinogenic, renal disorder, and diseases of kidneys, artillery, and nervous system [4,29]. The study observed that the presence of toxic metal ions along with the other ions in the effluents would have increased the contamination level in the surface and groundwater of the area. These toxic metal ions and their compounds caused extremely harmful to human health through water and foodstuff. As the human consume the toxic metal ions, might be accumulated in bones and other organs. The study observed that the surface water, groundwater, and soil were contaminated through the discharge of sugar mills untreated effluents in the study area, and the contamination process will continue in the future.

**Table 6.** Heavy metals parameters exceeded DoE-BD (2003) standard.

| Parameters (mg/L) | Type of sample | % of sample exceed DoE value | Maximum concentration | DoE-BD standard value |
|---|---|---|---|---|
| Fe | Eff | 100 .00 | 13.11 | 2.0 |
| | SW | 66.67 | 7.52 | 2.0 |
| | GW | 100.00 | 5.33 | 0.3–1.0 |
| Pb | Eff | 100 | 0.146 | 0.1 |
| | GW | 33.33 | 0.088 | 0.05 |
| Mn | GW | 100.00 | 1.085 | 0.05–0.1 |

*3.4. Impacts Anionic parameters*

The highest mean concentration of $Cl^-$ in the effluent, surface water, and groundwater samples were 81.52, 51.96, and 57.36 mg/L, respectively (Table 7). The highest mean concentration of $SO_4^{2-}$ in the effluent, surface water, and groundwater samples were 92.62, 58.35, and 50.05 mg/L, respectively (Table 7.). The highest mean concentration of $NO_3^-$ in the effluent, surface water, and groundwater samples were 37.75, 2.5, and 2.34 mg/L, respectively (Table 7).The highest mean concentration of $PO_4^{3-}$ concentrations of the effluent, surface water, and groundwater samples in the study area were 23.43, 1.21, and 1.03 mg/L, respectively. All the values were found within the standard permissible limits of IS-2000, NEQS-200, and DoE-BD (2003) standards [16–18]. Therefore, the anionic parameters would have caused any harm to human life and the environment.

**Table 7.** Mean values and standard deviations of anionic parameters in effluent, surface water and groundwater during Oct. 2014 (Pre-production) - Apr. 2016 (Post-production) at different locations.

| Parameters | Sample location | Effluent (mg/L) Mean ±SD | Surface water (mg/L) Mean ±SD | Groundwater (mg/L) Mean ±SD |
|---|---|---|---|---|
| $Cl^{-}$ | L-1 | 81.52 ±3.92 | 51.96 ±11.13 | 52.24 ±13.59 |
| | L-2 | 76.39 ±6.49 | 51.16 ±10.78 | 53.55 ±13.66 |
| | L-3 | 68.7 ±9.19 | 49.96 ±10.95 | 54.85 ±13.37 |
| | L-4 | 61.79 ±12.04 | 49.07 ±10.93 | 56.45 ±13.01 |
| | L-5 | 59.02 ±12.61 | 48.04 ±10.79 | 57.36 ±12.69 |
| $SO_4^{2-}$ | L-1 | 92.62 ±2.67 | 58.35 ±11.94 | 50.05 ±5.53 |
| | L-2 | 90.19 ±2.72 | 57.42 ±12.25 | 48.24 ±6.64 |
| | L-3 | 88.23 ±1.96 | 56.42 ±12.37 | 47.64 ±6.59 |
| | L-4 | 81.89 ±7.16 | 55.36 ±12.69 | 46.33 ±6.75 |
| | L-5 | 78.83 ±8.26 | 54.46 ±13 | 45.49 ±6.65 |
| $NO_3^{-}$ | L-1 | 37.75 ±3.06 | 2.5 ±0.63 | 2.34 ±0.24 |
| | L-2 | 36.3 ±2.49 | 2.44 ±0.62 | 2.26 ±0.22 |
| | L-3 | 33.76 ±1.37 | 2.32 ±0.6 | 2.16 ±0.25 |
| | L-4 | 32.15 ±1.58 | 2.21 ±0.57 | 2.11 ±0.24 |
| | L-5 | 30.55 ±1.95 | 2.15 ±0.56 | 2.04 ±0.27 |
| $PO_4^{3-}$ | L-1 | 23.43 ±7.11 | 1.21 ±0.28 | 1.03 ±0.43 |
| | L-2 | 22.03 ±6.82 | 1.19 ±0.27 | 1.01 ±0.43 |
| | L-3 | 21.09 ±6.49 | 1.16 ±0.27 | 0.99 ±0.42 |
| | L-4 | 20.35 ±6.41 | 1.13 ±0.27 | 0.97 ±0.42 |
| | L-5 | 19.51 ±5.94 | 1.06 ±0.27 | 0.95 ±0.41 |

### *3.5. Impacts on Human Health*

The study results illustrated that there were some toxic metal ions, including $Fe^{3+}$, $Pb^{2+}$, and $Mn^{2+}$ in the effluent, surface water, groundwater, and soil that exceeded the permissible limit of the DoE-BD standard. Besides, a large amount of the toxic metal ions were present in all various samples that exceeded the standard permissible limits concerned public health. These toxic metal ions and their compounds cause serious harm to human health through water and foodstuff. A flow diagram shows how the sugar mills effluent contaminated soil and water, and the consequences of the results cause harm to human and aquatic life (Figure 2). As the human consume toxic metal ions through foodstuff, they may accumulate in bones and other organs. Thus, it causes diseases like diarrhea, carcinogenic, renal disorder, kidney diseases, artillery, and nervous system.

The study results showed that surface water and groundwater were contaminated to some extent and are likely to be continued in the future due to randomly discharged the untreated effluents around the sugar mills effluent discharged area. The study suggested that every sugar mill has to be installed an effluent treatment plant (ETP) as well public awareness programs should be taken for the inhabitants around the mills' areas to reduce the pollution level and save human health and the environment.

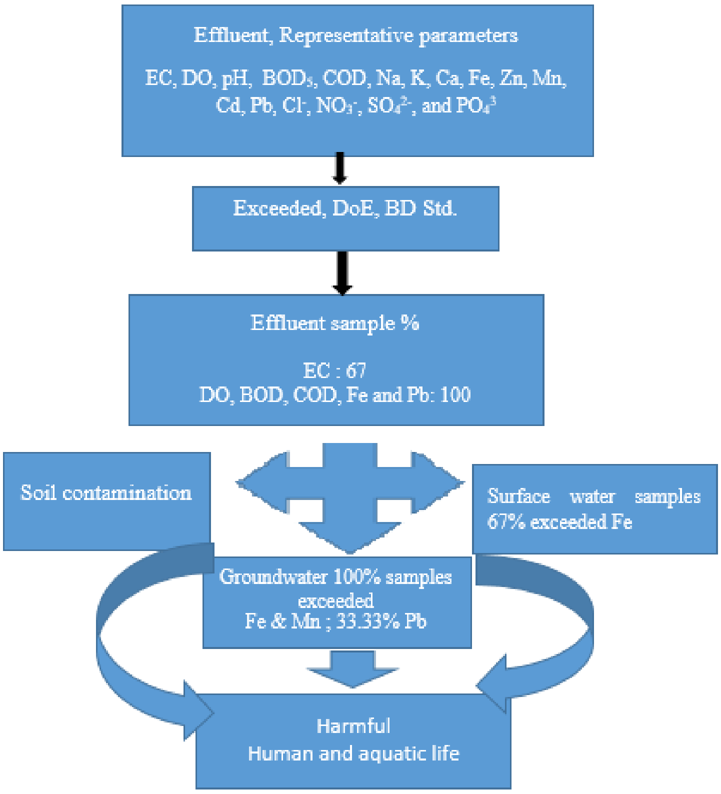


**Figure 2.** Representative parameters in the sugar mills effluents threaten for human and aquatic life through mobilization into surface and ground water.

## 4. Conclusions

The survey results illustrated that most of the people in the study areas have given their negative opinions regarding the impacts of sugar mills effluents on fish, crops, and human health life. They believed that the untreated effluents contained huge pollutants, which polluted the soil, waters, and human life around the sugar mills and effluent discharged drain adjacent areas. The higher BOD level in the effluents illustrated that the bacteria consumed the available oxygen in the water that declined the DO in water and reduced the survival condition for fish and other aquatic organisms. The study observed that some toxic metal ions, including $Fe^{3+}$, $Mn^{2+}$, $Pb^{2+}$, $Cu^{2+}$, $Zn^{2+}$, and $Cd^{2+}$ were present in the effluent, surface water, groundwater, and soil. The study observed that the $Pb^{2+}$ concentration of samples was exceeded the DoE-BD standard. Hence, the higher concentration of lead ($Pb^{2+}$) can accumulate in the human body through the food chain and causes harmful effects on various human organs. The study observed that the surface water, groundwater, and soil were contaminated through the discharge of sugar mills untreated effluents in the study area, and hence, immediate steps should be taken to treat the effluents before discharging into the environment.

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## Conflict of interest

The authors declare no conflict of interest.

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