PHYSICO-CHEMICAL AND MICROBIOLOGICAL WATER QUALITY ASSESSMENT OF MEHMOOD BOOTI DRAIN IN LAHORE CITY

Habib Ur Rehman,
Faakhar Raza,
Shazia Ghaffar

PHYSICO-CHEMICAL AND MICROBIOLOGICAL WATER QUALITY ASSESSMENT OF MEHMOOD BOOTI DRAIN IN LAHORE CITY

By:

Habib Ur Rehman[1], Faakhar Raza[1], Shazia Ghaffar[1]

Abstract

In this case study water quality assessment of Mehmood Booti Drain in Lahore city was carried out on the basis of major physico-chemical and microbiological parameters. The pH values (ranging from 6.65 to 7.34) of all samples collected from two sites of the drain were found to be within the safe limits of NEQS guidelines. EC values varied from 825 to 1266 μS/cm suggested low contamination of major cations and anions in drain water while the sulphate ions concentration was well below the permissible limits. Total Suspended Solids (TSS) values of all water samples were higher than permissible limit of 200 mg/L (473 to 2675 mg/L). Very low average value of dissolved oxygen (0.29mg/L), showed that drain water contain high quantity of organic matter. BOD values (146-432 g/L) were also found to be much higher than the permissible NEQS limit i.e. 80 mg/L. Relatively higher COD values were detected which ranged from 210 to 705 mg/L. The value of nitrates was in the range of 4.2 to 21.8 mg/L. The value of ammonium varied from 12.5 to 36.21 mg/L. The total Kjeldahl nitrogen of these samples ranged from 28.4 to 50.4 mg/L and found 38.3 mg/L on average. Bacteriological analysis showed that water samples were heavily contaminated with total and fecal contamination. The maximum count of total coliform was noted $9.6x10^7$ and the minimum count was 9×10^4. Maximum Fecal coliform count was 8.8×10^6 and the minimum count was 2.0×10^4.

Keywords: Water Quality Assessment, Physico-Chemical Parameters, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Mehmood Booti Drain

Introduction

Pakistan's growing population and depleting reserves are intensifying pressure on its water resources, pushing the country towards shortage and famine. In 2006, per capita water availability for irrigation was 1,100 cubic meters—barely above the 1,000 cubic meters minimum required to avoid being classified as water-short [1]. Water shortage has meant that access to potable drinking water is limited in many areas. The problems are exacerbated in the major cities by over extraction of groundwater and resulting in falling water tables. As a result, groundwater quantity has traditionally been a priority over quality issues in Pakistan. While this disaster demands to safe the quality of this small quantity of water [2].

Lahore is second largest city of Pakistan, lies in the upper Indus plain near the Indian border, at 31°34′N 74°20′E (31.560000 North, 74.35000 East). Ravi River is smallest of the five rivers of Punjab. Just above the Lahore city, the course of stream is carefully directed by the Mahmood Buti Bund, which keeps it to one channel and protect the city from the havoc of the floods. As much as 1,307.08 tones hazardous and untreated waste, mostly industrial, is going into the Ravi on a daily basis, making it poisonous [3]. As per the study, share of district Lahore in polluting the Ravi is 56 percent i.e. is 728.75 tons per day. About 10 drains and pumping stations and five industrial

[1] Pakistan Council of Research in Water Resources (PCRWR) Lahore, Pakistan
habibchemist786@gmail.com, shazia-ghaffar@hotmail.com, Faakharraza@gmail.com

wastewater drains were throwing over 2,000 cusec municipal sewage and toxic industrial effluents into the river. It revealed that according to international standards, the level of biological official demand (BOD) in the river water should be 80 mg/L whereas the level of BOD in the water of 10 drains and pumping stations ranged between 129 mg/L and 430 mg/L. Likewise, BOD in the water of five drains throwing toxic industrial waste into the river ranged between 24 mg/L and 360 mg/L [4].

The EPA conducted a study of drains which are discharging municipal and industrial water in the Ravi. According to the study Babu Sabu Drain, Lahore, is discharging 270.7 cusec waste water per second in the river, Furukhabad Drain 219 cusec, Main Out Fall Drain193 cusec, Gulshan-e-Ravi Drain 243.5 cusec , Hudiara Drain 535.7 cusec, Shahbagh Drain 139 cusec, Sukhnehr Drain 313.6 cusec, Buda Ravi Drain 41.9 cusec, Foresh Colony Drain 15.37 cusec, Muhmood Booti Drain 20.87 cusec, Shahdra Town Drain 21.87 cusec, Summundari Drain, Faisalabad, 400 cusec, Deg Nullah/Jaranwal Drain, Faisalabad, 100 cusec, Gojra Drain, Toba Tek Singh, 45 cusec, and Sukhrawa Drain, Shiwal is discharging 53 cusec liquid waste per second in the river [5]. The toxicity of water and plankton in the River Ravi stretchfromLahore siphon to Baloki head works and related effluent discharging tributaries has been studied. [6]. It was reported that there is the serious groundwater issue which is influencing health metabolic system [7]. The residue of hydrocarbons, organic and inorganic pollutants, moving along fault, leaching and seepage are contaminating the ground water aquifer which can be the source of drinking water [8].

In present study a survey was conducted in Lahore for waste water quality assessment from two identified sites of Mehmood Booti Drain. The aim of this study was to record different physico-chemical parameters and microbiological parameters like pH, Temperature, Total Suspended Solids, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Relative Humidity (rH), Sulphate, Total Hardness, Nitrate as N, Ammonium as N, Total Kjeldhal Nitrogen and Microbiological contamination. This study uniquely combines detailed water quality profiling with a focus on the linkage between urban wastewater discharge and downstream riverine health. The data aim to enhance understanding of pollutant sources, assess compliance with environmental standards, and provide actionable insights for wastewater management strategies. This research will be valuable for environmental scientists, policymakers, and water resource managers as it helps identify the main sources of pollution

Materials and Methods

The water quality assessment of Mehmood Booti Drain in Lahore, a densely industrialized area, was conducted following the Standard Operating Procedures (SOPs) set forth by the American Public Health Association (APHA) for wastewater sampling and analysis [9]. Sampling was carried out at two key sites along the drain to represent different points of possible industrial discharge. Each sample was collected in sterilized glass bottles and immediately preserve to maintain integrity until analysis.

Location of Sampling Points

Mehmood Booti drain was selected for the study. First sampling point (site-1) is located near the Lahore Compost at Band Road Lahore at Latitude 31°36’35”, Longitude 74°22’38” and at 204m elevation, whereas the second point (site-2) is near the Rani

Chowk of Village Bhamma at Latitude 31°37'10", Longitude 74°20'04"and at 200m elevation The Locations of both sampling points are marked in the figure (1).

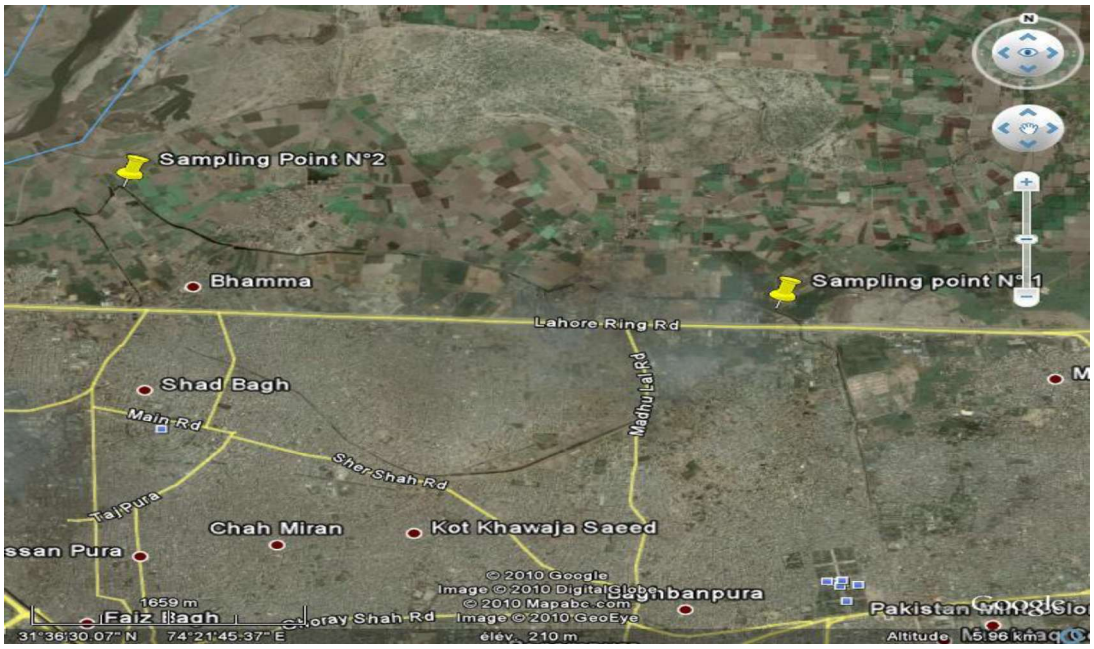


Figure-1 Sampling sites of Mehmood Booti drain

Sample Collection

The waste water sampling was made for continuous five days from 1st June to 5th June 2020. Two water samples were collected daily from each site (one in morning and other in evening time). In morning session water samples were collected round about 10 O'clock. This time maximum effluent flow was observed in the sewage drains of the city. In evening session, the samples were taken about 6 O'clock.

The samples were collected from the representative points with the help of the auto-sampler at depth of about 1.5 feet from surface. The sample of each shift and date was given a specific identified detailed code, showing the sample number and site identification, e.g. 7-S-1 means sample number 7 and site number 1. (Table 1)

Table-1: Sampling Information and weather conditions

Serial No.	Site No.	Time	Sample ID	Temper-ature °C	General Weather condition*	Relative Humidity (Percent)
1	1	10:15	1-S-1	39.3	Dry and sunny	24
2	2	10:35	2-S-2	42.0	Dry and sunny	27
3	1	18:04	3-S-1	39.4	Dry and sunny	20
4	2	18:22	4-S-2	36.2	Dry and sunny	22
5	1	10:10	5-S-1	39.0	Dry and sunny	20
6	2	10:35	6-S-2	45.4	Dry and sunny	22
7	1	18:10	7-S-1	38.3	Dry and sunny	24
8	2	18:32	8-S-2	41.6	Dry and sunny	20
9	1	10:00	9-S-1	30.3	Sunny and airy	29
10	2	10:38	10-S-2	29.9	Sunny and airy	28
11	1	18:05	11-S-1	39.2	Cloudy and dry	26
12	2	18:40	12-S-2	32.8	Cloudy and airy	45
13	1	9:50	13-S-1	36.6	Cloudy and dry	40
14	2	10:30	14-S-2	33.4	Cloudy and airy	49
15	1	17:30	15-S-1	36.8	Cloudy and airy	36
16	2	18:15	16-S-2	28.4	overcast	59
17	1	9:53	17-S-1	36.4	Sunny and airy	33
18	2	10:25	18-S-2	41.5	Sunny and airy	26
19	1	17:55	19-S-1	35.9	Sunny and airy	28
20	2	18:15	20-S-2	33.7	Sunny and airy	28
Minimum				**28.4**		**20**
Maximum				**45.4**		**59**

The parameters (subject to change during storage and shifting to laboratory) such as pH, electrical conductivity, temperature, dissolved oxygen, weather temperature, sample temperature and relative humidity were determined at the site in the field. For rest of the parameters the samples were preserved in good conditions according to the requirements of each parameter. The detail of the preservation is summarized in the table 2.

Table-2 Types of water samples & Preservative

Type	Sites	Parameter	Preservative	Quantity added
A	All	Microbiology	1.8% solution of sodium thiosulfate as dechlorinating agent	0.1 mL/100mL
B	All	COD, Total Kjeldahl Nitrogen (TKN)	Conc. H_2SO_4 to maintain pH less than 2	1mL/500mL
C	All	Nitrate (N)	1M Boric acid	5mL/500mL
D	All	Hardness, pH, EC,	No Preservative added	None
E	All	BOD	Allyl Thiourea	1mL/500mL
F	All	Stored at 0°C as	No Preservative added	Not required
G	All	Ammonium (N)	Hydrochloric Acid to	1mL/500mL

The samples collected from the site were transferred to the lab in ice box to keep the chemical and microbial constituents as stable as possible. All the collected samples were analyzed in the laboratory by MPN dilution method for the waste water samples. Dilutions were made with sterilized peptone water.

Analysis of Water Samples

The water samples were analyzed for major parameters namely Temperature, Total Suspended Solids, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Relative Humidity (rH), Sulphate, Total Hardness, Nitrate as N, Ammonium as N, Total Kjeldhal Nitrogen and Microbiological contamination. Some necessary parameters were tested at site, while the others were analyzed in the laboratory. For quality assurance the blank and certified reference materials were run on the instruments before the analysis of the samples. The samples were analyzed for the committed parameters using the test methods given in Table 3.

Table-3 Water Quality Parameters and Standard method of Analysis [10]

S. #	Water Quality Analysis Parameters	Test Methods
1.	Hardness (mg/L)	EDTA Titration, Standard Method (1992)
2.	TSS (mg/L)	Colorimeter DR2800
3.	Sulfate (mg/L)	4500 SO_4, Standard Method (1992).UV-Visible Spectrophotometer, SPECORD 200, Analytikjena
4.	Nitrate-N (mg/L)	4500 NO_3, Standard Method (1992), UV-Visible Spectrophotometer, SPECORD 200, Analytikjena

5. Microbiological Analysis	APHA (1992 Edition) 9221B, Multiple Tube Fermentation Technique for Colform Group (MPN Method)
6. NH_4^+ -N	Salicylate Method, 10031Colorimeter DR2800
7. Water Temperature	Thermometer, Immersion GH Zeal England N2 Filled
8. BOD	5-Day BOD method
9. COD	Reactor Digestion Method 8000, Colorimeter DR-2800
10. DO	DO Meter, Model 970; Jenway
11. Total Nitrogen	Total Kjeldahl Nitrogen Method (TKN)
12. Relative Humidity (rH)	With Relative Humidity Meter
13. pH	pH Meter, Hanna Instrument Model HI 991301, Italy

Bacteriological Parameter (with dilution method for waste water analysis

Bacteriological analysis of water samples was conducted using the multiple fermentation technique, following APHA, AWWA, and WEF standards. Seven tubes each of MacConkey Broth (for total coliforms) and Brilliant Green Lactose Bile Broth (for fecal coliforms) were inoculated with varying volumes of water and incubated at 35°C and 44°C respectively for 48 hours. Gas and acid production indicated positive presumptive tests, and results were reported as Most Probable Number (MPN) per 100 mL.

Results and Discussion

Weather Conditions at the Time of Sampling

The lowest temperature (28.4°C) was recorded on 4th June 2020 at site 2 but the highest temperature (45.4°C) was observed on 2nd June 2020. The average temperature during the whole monitoring remained 36.80°C. Hot air flows with sunny days prevailed during most of the days but in some sessions cool and cloudy conditions were also prevailed. The humidity on the average remained about 30% but it was noted 59% in a single case due to airy and overcast condition [Table 1] A line graph illustrates the daily temperature variations, with indicators highlighting the extreme temperatures on June 2 and June 4, and a reference line for the average temperature. The humidity levels are presented on the same graph using a bar graph, showing fluctuations against the temperature trends. This visual presentation highlights the inverse relationship between temperature and humidity, especially on days with notable weather shifts as shown in figure 2.

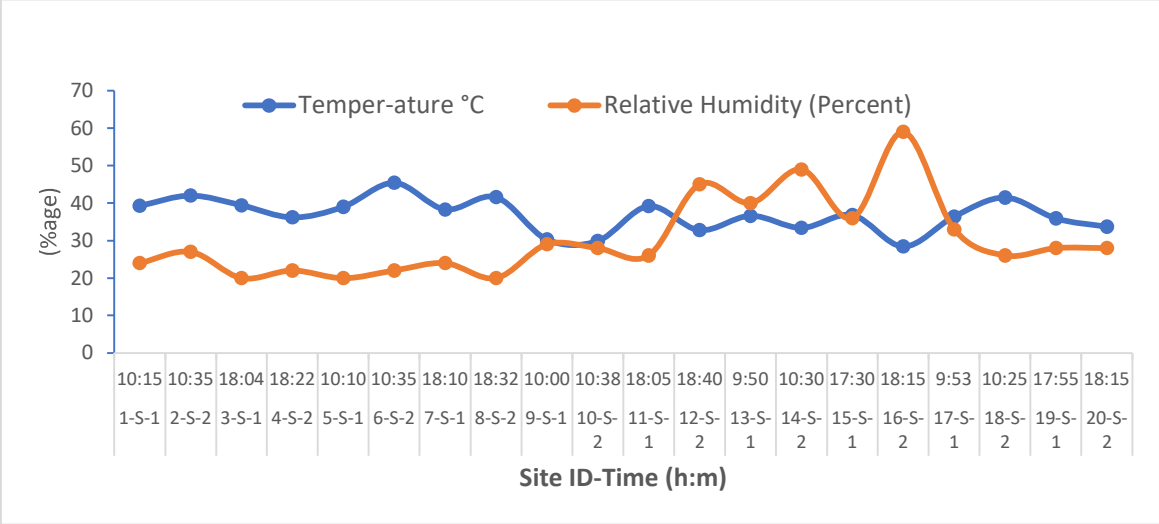


Figure-2 Temperature (ºC) and humidity (% age)

Physico-Aesthetic Parameters

Table 4 presents analytical data for physical parameters (pH, EC, DO, TSS, and temperature). The pH, governed by the carbonate–bicarbonate–CO_2 system, ranged from 6.65 to 7.34, indicating all samples fall within the safe limits of NEQS guidelines (6-9).

EC of the water samples was 825 to 1266 μS/cm and on average to 1065 (Table 4). As EC indicates the concentration of salts in water sample, so it can be inferred that there is a low contamination of major cations and anions in drain water.

Table-4: Physico-Aesthetic Parameters

Serial No.	Sample ID	Sample Temperatu	EC (μS/c	TSS (mg/	pH	DO (mg/	BOD (mg/ L)	COD (mg/
Permissible limits		**=<3°C**	**NGVS**	**200**	**6-9**	**<4**	**80**	**150**
1	1-S-1	36.0	1136	558	7.1	0.41	190	241
2	2-S-2	34.7	1070	705	7.1	0.42	179	210
3	3-S-1	32.5	1266	2215	6.6	0.36	212	267
4	4-S-2	32.3	1179	1010	7.1	0.32	218	287
5	5-S-1	33.3	1128	743	7.2	0.35	235	332
6	6-S-2	33.4	966	473	7.2	0.26	267	309
7	7-S-1	35.3	1073	828	7.1	0.13	432	705
8	8-S-2	33.8	1110	898	7.1	0.25	261	318
9	9-S-1	29.6	1018	756	7.2	0.21	238	405
10	10-S-2	32.6	980	782	7.1	0.19	365	591
11	11-S-1	33.4	1061	980	7.2	0.20	272	402
12	12-S-2	30.2	1055	996	7.0	0.27	250	337
13	13-S-1	31.6	1057	872	7.1	0.23	273	442
14	14-S-2	32.5	902	784	7.1	0.39	225	296
15	15-S-1	32.7	1071	924	7.2	0.25	290	413
16	16-S-2	29.0	825	2675	7.0	0.18	367	529
17	17-S-1	31.1	1060	540	7.3	0.23	261	334
18	18-S-2	32.1	1015	1254	7.0	0.38	176	266

19	19-S-1	32.9	1213	2410	6.8	0.42	146	250
20	20-S-2	33.4	1109	1785	7.0	0.38	161	270
Minimum		**29.0**	**825**	**473**	**6.6**	**0.13**	**146**	**210**
Maximum		**36.0**	**1266**	**2675**	**7.3**	**0.42**	**432**	**705**
Average		**32.6**	**1065**	**1109**	**7.1**	**0.29**	**146**	**210**

Total Suspended Solids (TSS) in the all collects water samples were found crossing the permissible limits of 200 mg/L (Table 4). The TSS value ranges from 473 to 2675 mg/L in these samples. The high values of TSS, results in increase of temperature and depletion of dissolved oxygen [10].

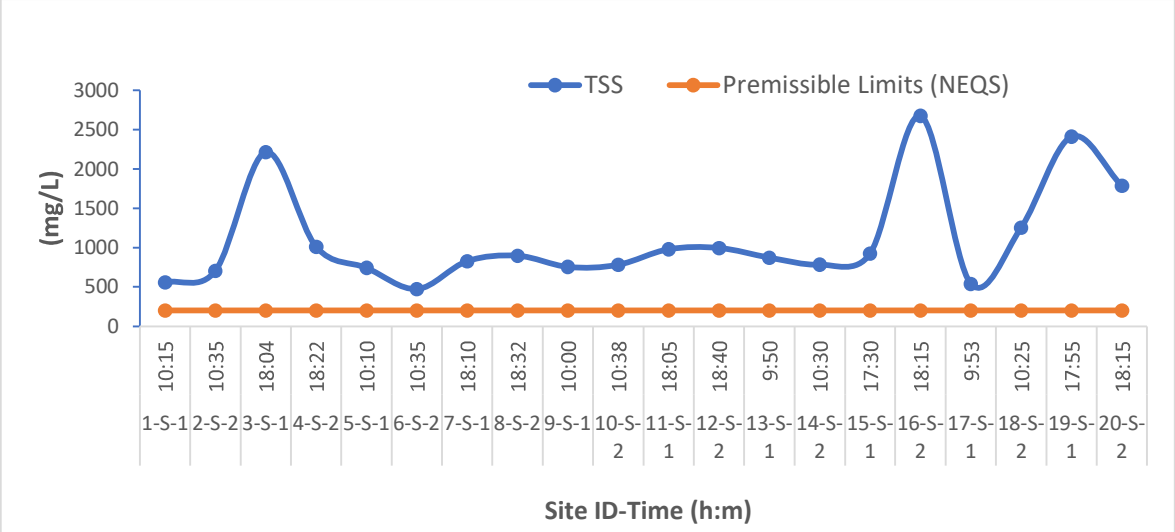


Figure-3 Total suspended solids

The graph as shown in figure 3 illustrates the TSS variations across the samples, clearly showing the degree to which each sample surpasses the permissible threshold. This visual highlight the potential impact of high TSS on water quality, temperature, and oxygen availability, underscoring the need for intervention to control suspended solids in these water sources

The dissolved oxygen (DO) levels in the drain water samples were notably low, ranging from 0.13 to 0.42 mg/L, with an average of 0.29 mg/L. These values fall significantly below the minimum recommended level of 2 mg/L necessary to sustain aerobic conditions and prevent harmful effects on aquatic life. [12]. The figure 4 visually emphasizes this trend, displaying DO levels for each sample, all of which are far below the threshold. The low DO levels reflect high organic matter content in the water, likely leading to anaerobic conditions that produce bad odors. This graphic underline the urgent need for interventions to reduce organic load and improve oxygenation to protect aquatic ecosystems and environmental quality

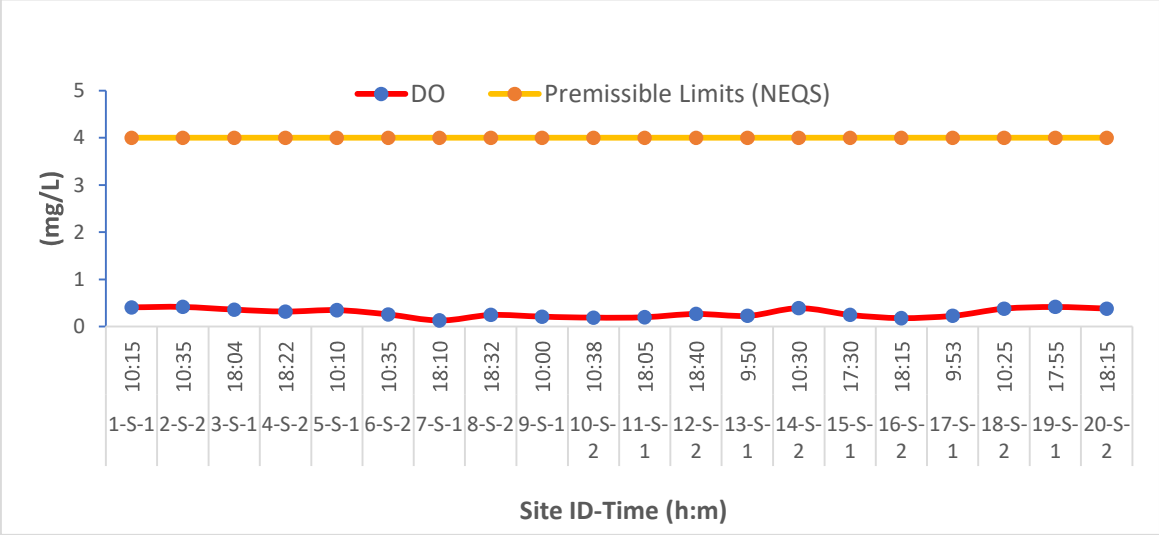


Figure-4 Dissolved Oxygen (DO)

Biological Pollutants

Biological oxygen demand (BOD) of the collected samples found in the range of 146 to 432 mg/L. These values are much higher than the permissible NEQS limit i.e. 80mg/L. So, these values show that the water dumping in the River Ravi requires treatment for the safety of the River Ravi and the environment. The Biological Oxygen Demand (BOD) levels in the collected water samples ranged from 146 to 432 mg/L, significantly exceeding the NEQS permissible limit of 80 mg/L (Table 4). The graph illustrates (Figure 5) these elevated BOD levels across samples, each far surpassing the threshold. Such high BOD values indicate a substantial presence of organic pollutants, highlighting the urgent need for treatment before discharging this water into the River Ravi. Reducing BOD is critical to protect the river's ecological balance and prevent further environmental degradation [13]. This graphical representation emphasizes the severity of pollution and the necessity for wastewater management

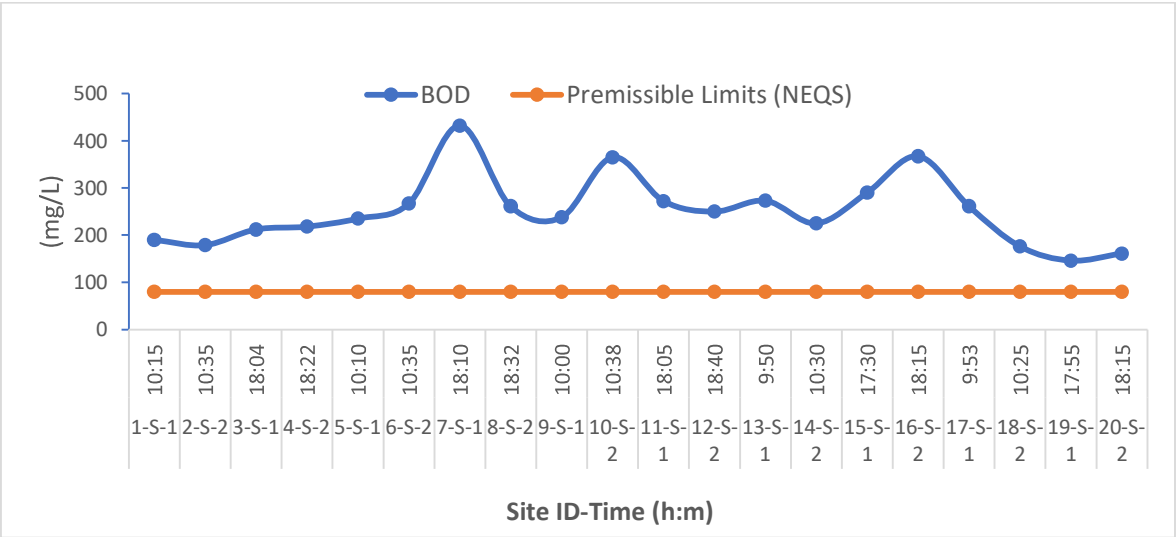


Figure-5 Biological oxygen demand (BOD)

Chemical Oxygen Demand (COD), closely linked with BOD and DO, serves as an indicator of organic and chemical pollution. COD values in the drain ranged from 210 to 705 mg/L, providing strong evidence of biological contamination (Table 4).

The Chemical Oxygen Demand (COD) levels in the drain water samples ranged from 210 to 705 mg/L, reflecting substantial organic and chemical contamination. The graph demonstrates (Figure 6) these elevated COD values, underscoring the drain's high levels of biological pollution. Since COD is closely linked to Biochemical Oxygen Demand (BOD) and Dissolved Oxygen (DO), the high COD values further corroborate the findings of low DO levels and elevated BOD, indicating an environment rich in organic matter. These conditions are detrimental to water quality, signaling the need for treatment to reduce organic pollution and prevent negative impacts on aquatic life

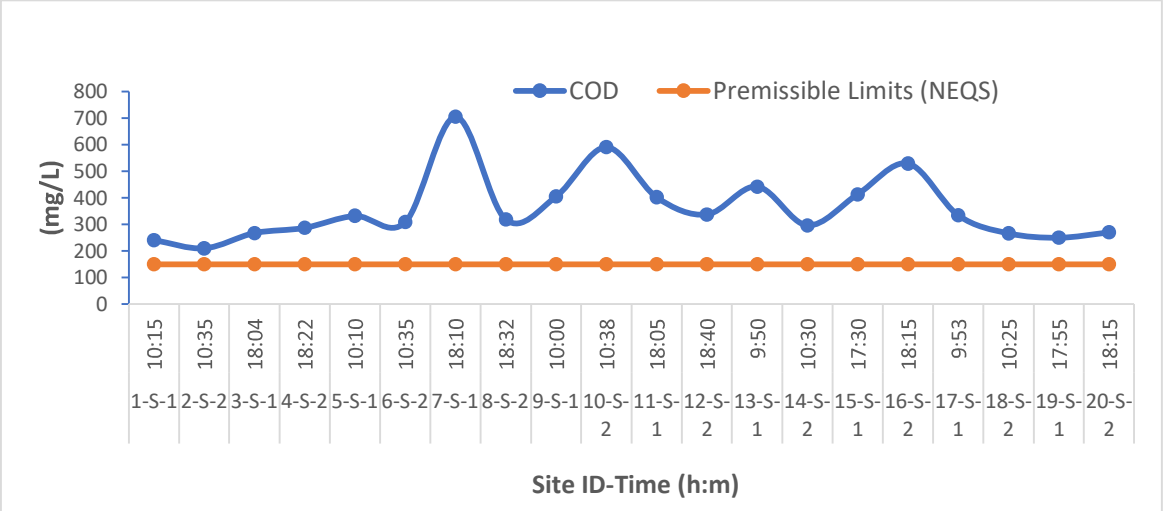


Figure-6 Chemical oxygen demand (COD)

Nitrogen Contamination

Nitrogenous contaminants in water samples included nitrates (4.2–21.8 mg/L), ammonium (12.5–36.21 mg/L), and total Kjeldahl nitrogen (28.4–50.4 mg/L; avg. 38.3 mg/L). Nitrates mainly originate from biological oxidation, while high ammonia levels cause foul odor and are toxic to freshwater organisms at 0.53–22.8 mg/L. Detailed data are presented in Table 5.

Table-5: Nitrogen Contamination

Sample ID	Nitrate (mg/L)	Ammonium (mg/L)	Total Kjeldahl Nitrogen	Sulphate (mg/L)	Total Hardness (mg/L)	Total Coliform	Fecal Coliform
Permissible	NGVS	40	NGVS	600	NGVS	MPN/100 mL	MPN/100 mL
1-S-1	10.5	32.25	44.4	10	235	$2.0x10^7$	$5x10^6$
2-S-2	10.7	36.21	50.4	8	235	$8.8x10^6$	$2.2x10^6$
3-S-1	4.2	24.65	30.2	40	230	$3.8x10^5$	$2.0x10^5$
4-S-2	6.5	31.57	38.8	9	230	$2.4x10^6$	$3.8x10^5$
5-S-1	12.9	36.02	49.6	16	235	$2.1x10^7$	$7.6x10^6$
6-S-2	8.7	19.51	32.2	47	215	$3.8x10^7$	$8x10^6$
7-S-1	16.2	29.47	46.2	17	230	$9.6x10^7$	$8.8x10^6$
8-S-2	21.8	27.68	49.9	25	240	$3.8x10^7$	$7x10^6$

Sample ID	Nitrate (mg/L)	Ammonium (mg/L)	Total Kjeldahl Nitrogen	Sulphate (mg/L)	Total Hardness (mg/L)	Total Coliform	Fecal Coliform
9-S-1	17.1	15.1	33	13	235	$2.1x10^7$	$5x10^6$
10-S-2	18.8	12.5	32.6	14	215	$1.4x10^7$	$7.6x10^6$
11-S-1	19.6	22.24	43.8	19	230	$1.1x10^7$	$2x10^6$
12-S-2	12.2	22.78	36.2	39	235	$8.8x10^6$	$2x10^6$
13-S-1	15.9	19.2	36.2	14	225	$9x10^6$	$2.2x10^6$
14-S-2	8.9	18.58	28.4	18	220	$3.8x10^7$	$7.6x10^6$
15-S-1	13.5	17.2	31	20	230	$1.5x10^5$	$5x10^4$
16-S-2	21.4	18.9	41.6	67	240	$1.2x10^5$	$8.8x10^4$
17-S-1	19.7	14.6	35.8	6	225	$9.6x10^5$	$8.8x10^4$
18-S-2	18.1	15.74	34.9	9	230	$9x10^4$	$2.0x10^4$
19-S-1	21.4	12.86	35.8	124	230	$3.8x10^5$	$9x10^4$
20-S-2	15.6	18.9	35.6	55	240	$1.5x10^5$	$2.2x10^4$
Minimu	**4.2**	**12.5**	**28.4**	**6**	**215**	**$9x10^4$**	**$2.0x10^4$**
Maximu	**21.8**	**36.21**	**50.4**	**124**	**240**	**$9.6x10^7$**	**$8.8x10^6$**
Average	**14.7**	**22.30**	**38.33**	**28.5**	**230**	**$4.4x10^6$**	**$5.3x10^5$**

Chemical Contamination

Water hardness, imparted by calcium and magnesium ions, ranged from 215 to 240 mg/L. Sulphate concentrations varied from 6 to 124 mg/L, remaining well below NEQS permissible limits. Detailed chemical data are presented in Table 5.

Microbiological Contamination

The maximum count of total coliform was noted in sample is $9.6x10^7$ and the minimum count was $9x10^4$. Maximum fecal coliform count was $8.8x10^6$ and the minimum count was $2.0x10^4$. The analytical values of Total Coliform and Fecal Coliform (E. coli) are presented in Table-5.

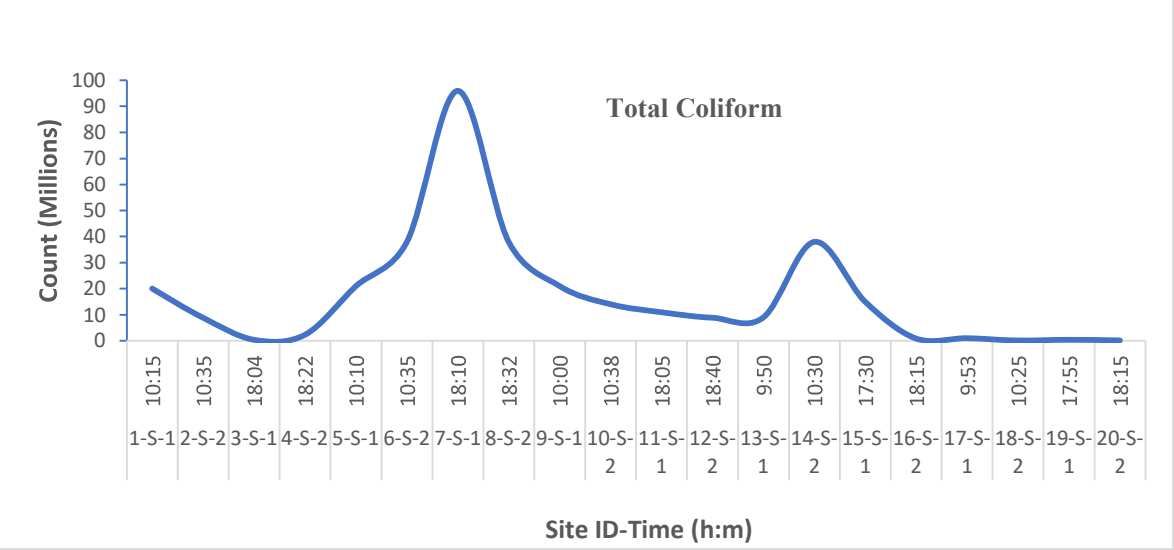


Figure 7 Total Coliform

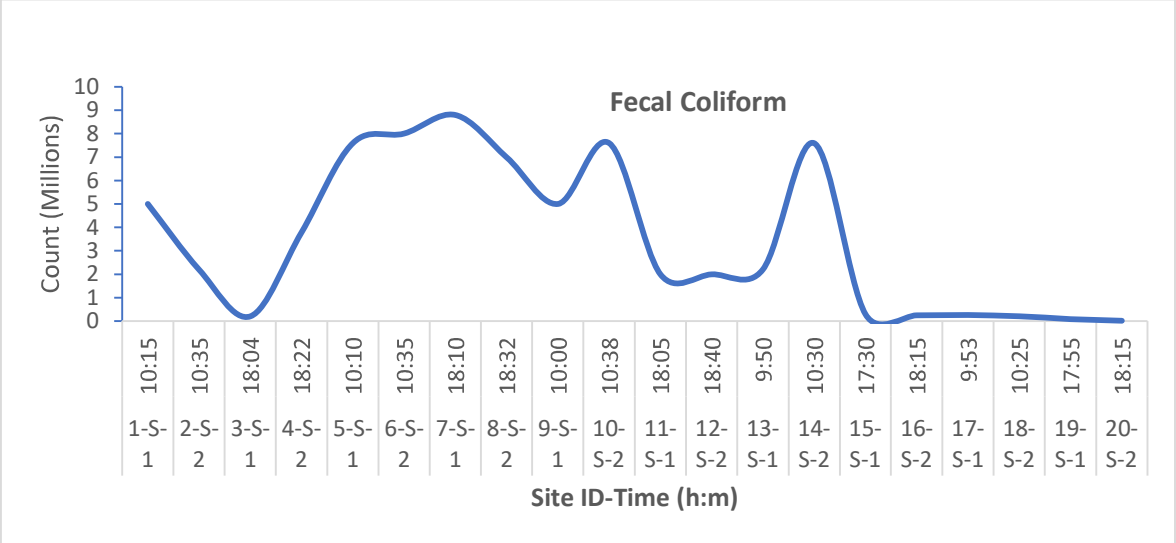


Figure-8 Fecal Coliform

Coliform presence indicates biological pollution, with drain water heavily contaminated by total and fecal coliforms. Figures 7 and 8 show counts exceeding safe limits. Untreated organic matter containing fecal coliforms can deplete dissolved oxygen during aerobic decomposition, threatening fish and aquatic life [12].

Conclusion

The water quality assessment of the Mehmood Booti Drain in Lahore reveals significant contamination, particularly in terms of organic and suspended solids content. While pH values (6.65–7.34) were within the NEQS guideline, indicating overall acidity/alkalinity stability, other parameters exceeded permissible limits. Elevated Electrical Conductivity (EC) levels (825–1266 µS/cm) suggest moderate ionic contamination. High levels of Total Suspended Solids (473–2675 mg/L) surpass the NEQS limit, indicating considerable particulate pollution. Dissolved oxygen (DO) levels were critically low (0.29 mg/L), reflecting high organic load, with Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) levels (146–432 mg/L and 210–705 mg/L, respectively) far above the acceptable standards, further confirming organic pollution. Nitrate levels (4.2–21.8 mg/L) and elevated ammonium and Total Kjeldahl Nitrogen (TKN) values reveal nutrient loading, which can lead to eutrophication if discharged untreated into waterways.

Recommendations

1. **Treatment Interventions**: Establishment of wastewater treatment facilities is essential to reduce organic load, TSS, BOD, and COD levels before the water is discharged into the River Ravi.
2. **Aeration Techniques**: Implementing aeration systems can increase dissolved oxygen levels, which would help reduce the impact of organic pollution and improve conditions for aquatic life.
3. **Nutrient Control**: Reducing nutrient concentrations (nitrates and ammonium) is crucial to prevent eutrophication. This could involve adopting nutrient-removal techniques in treatment processes.

4. **Regular Monitoring**: Continuous monitoring of physico-chemical and microbiological parameters is recommended to detect pollution trends and assess the effectiveness of treatment interventions over time.
5. **Public Awareness and Policy Enforcement**: Raising awareness about the impacts of untreated waste discharge and enforcing regulatory compliance with NEQS can encourage industrial and municipal entities to take responsibility for their effluents.
6. **Green Buffer Zones**: Establish green buffer zones with vegetation along the drain to naturally filter runoff, potentially reducing suspended solids and nutrient concentrations through bio-filtration

References

1. Ashraf, S., Ali, M., Shrestha, S., Hafeez, M. A., Moiz, A., & Sheikh, Z. A (2022) Impacts of climate and land-use change on groundwater recharge in the semi-arid lower Ravi River basin, Pakistan. Groundwater for Sustainable Development. 17, 100743. https://doi.org/10.1016/j.gsd.2022.100743
2. Asim Mehmood., S.A., Samia Saif (2014) Assessment of the impact of effluent disposal in river ravi at lahore on the water quality for irrigation and recreational purposes at upstream of Balloki Barrage, Pakistan. Journal of Biodiversity and Environmental Sciences 5, 241-254.
3. Arnold E. Greenberg, A.D.E. (1992) Standard Methods For the Examination of Water and Waste Water American Public Health Association (APHA), USA.
4. Batool, R., Mahmood, K., Ahmad, S., & Naeem, M (2019) Geographic scenario of drinking water quality of Lahore metropolitan, Pakistan, in response to urbanization and water demand: A GIS perspective. Applied Ecology and Environmental Research, 17(2), 3973-3988. DOI: http://dx.doi.org/10.15666/aeer/1702_39733988
5. Haynes R, Murtaza G, Naidu R (2009) Inorganic and organic constituents and contaminants of biosolids: implications for land application. Adv Agron 104:165–267. https://doi.org/10.1016/S0065-2113(09) 04004-8
6. Javed, M. (2005) Heavy Metal Contamination of Freshwater Fish and Bed Sediments in the River Ravi Stretch and Related Tributaries. Pakistan Journal of Biological Sciences 8(10), 1337-1341.
7. Mitchell, E., Frisbie, S. and Sarkar, B. (2011) Exposure to multiple metals from groundwater—a global crisis: Geology, climate change, health effects, testing, and mitigation. Metallomics 3(9), 874-908.
8. Jin-Yong Lee., J.-Y.C., Seok-Young Lee, Kang-Kun Lee (2001) Factors affecting the distribution of hydrocarbon contaminants and hydrogeochemical parameters in a shallow sand aquifer. Journal of Contaminant Hydrology 50, 139–158.
9. Standard Methods for the Examination of Water and Waste Water (APHA) 18th Edition (1992) Jointly published by American Public Health Association, American Water Works Association and Water Environment Association Joint Editorial Board: Arnold E. Greenberg. APHA Chairman Lenore S. lesceri, WEF Andrew D. Eaton, AWWA
10. Soller, J.A., Nellor, M.H., Cruz, C.J. and McDonald, E. (2015) Human health risk associated with direct potable reuse – evaluation through quantitative relative risk assessment case studies. Environmental Science: Water Research & Technology 1(5), 679-688.
11. Shakir, H.A., Qazi, J.I. and Chaudhry, A.S. (2013) Monitoring the impact of urban effluents on mineral contents of water and sediments of four sites of the river Ravi, Lahore. Environ Monit Assess 185(12), 9705-9715.
12. Smith SR (2009) A critical review of the bioavailability and impacts of heavy metals in municipal solid waste composts compared to sewage sludge. Environ Int 35:142–156. https://doi.org/10.1016/j.envint.2008.06.009

13. Telliard WA (1989) Sampling procedures and protocols for the national sewage sludge survey (no. PB-93-156974/XAB). Environmental Protection Agency, Washington, DC Office of the Assistant Administrator for Water
14. U.S. Environmental Protection Agency (EPA). Washington, DC (2008). "Analytical Methods Approved for Drinking Water Compliance Monitoring under the Total Coliform Rule." June 2008
15. Zebarth BJ, McDougall R, Neilsen G, Neilsen D (2000) Availability of nitrogen from municipal biosolids for dryland forage grass. Can J Plant Sci 80:575–582. https://doi.org/10.4141/P99-160