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Characterization of Drain Surface Water: Environmental Profile, Degradation Level and Geo-statistic Monitoring

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Abstract
The physico-chemical characterization of the surface water. Samples was carried out collected from nine sampling points of drain passing by the territory of Hafizabad city, Punjab, Pakistan. The water of drain is used by farmers for irrigation purposes in nearby agricultural fields. Twenty water quality parameters were evaluated in three turns and the results obtained were compared with the National Environmental Quality Standards (NEQS) municipal and industrial effluents prescribed limits. The highly significant difference ($p<0.01$) was recorded for the content of phenols, carbonyl compounds, cyanides, dissolved oxygen, biological oxygen demand, total soluble salts, total dissolved salts, nitrates and sulphates, whereas, the concentration of magnesium, potassium and oil & grease differed significantly ($p<0.05$) with respect to the sampling points on average basis. Non-significant difference ($p>0.05$) was noted for temperature, pH, electrical conductivity, hardness, calcium, sodium, chemical oxygen demand and chloride among water samples from different sampling points. Furthermore, the experimental results of different water quality parameters studied at nine sampling points of the drain were used and interpolated in ArcGIS 9.3 environment system using kriging techniques to obtain calculated values for the remaining locations of the Drain.

Keywords: Degradation; Drain; Kriging; Monitoring.

Introduction

During the last few decades shortage of water has become a critical problem in Pakistan as well as in several other developing countries. In Pakistan, both rural and urban populations are facing severe shortage of water due to continuous increase of pollution and agriculture expansion. As result, in many areas, people and farmers use polluted water for drinking and irrigation purposes [1]. In Pakistan, due to lack of proper facilities of waste disposal just 1% of the wastewater is treated before being discharged into water bodies, thus rendering water unsuitable for drinking, industrial, agricultural and recreation purposes etc. [2]. Moreover, water pollution and accumulation of metal in freshwater ecosystems has become a global problem both in developing and developed countries. Accumulation of metals and various diseases in aquatic organisms without producing visible signs of warning for the potential consumer are linked to the water. The polluted water largely influence human, plants and aquatic life, moreover certain pollutants enters into food chain and ultimately reach at higher trophic level such as human [3,4]. It is therefore recommended that

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more strict methods of waste effluent management should be adopted to reduce the inputs of pollutants into the water bodies to preserve ecosystem and save human beings from various water borne diseases [5]. For this purpose modern geostatistic techniques have been developed for large scale environmental monitoring and allow spatial visualization of the contaminated areas by mapping. An interpolation technique known as kriging is used extensively for this purpose. Prediction maps produced by kriging interpolation provided useful information for hazard assessment that can help decision makers in taking appropriate actions to protect public health [6].

Many researchers focused to investigate the drivers responsible for water pollution, types and quantification of pollutants and their hazardous impact on floral and faunal populations [7]. Keeping in view the fact that domestic, industrial, commercial and agricultural sources are the key drivers of water pollution in Pakistan, hence, the investigation of physical, chemical and biological characteristics of water can be helpful to saving different water resources from further degradation and contamination. The farmers use the under study drain water for irrigation in nearby agricultural fields. Therefore the present study was designed to check the level of contaminants and pollutants in water of the drain passing by the territory of district Hafizabad, Punjab, Pakistan. The city is recognized worldwide for its high quality rice products.

Materials and Methods

To establish Environmental profile of drain passing through the surrounding areas of Hafizabad city Pakistan and to investigate its pollution level, based on the initial survey, nine sampling stations were selected for the collection of water samples. These sampling stations are shown in the (Fig.1).

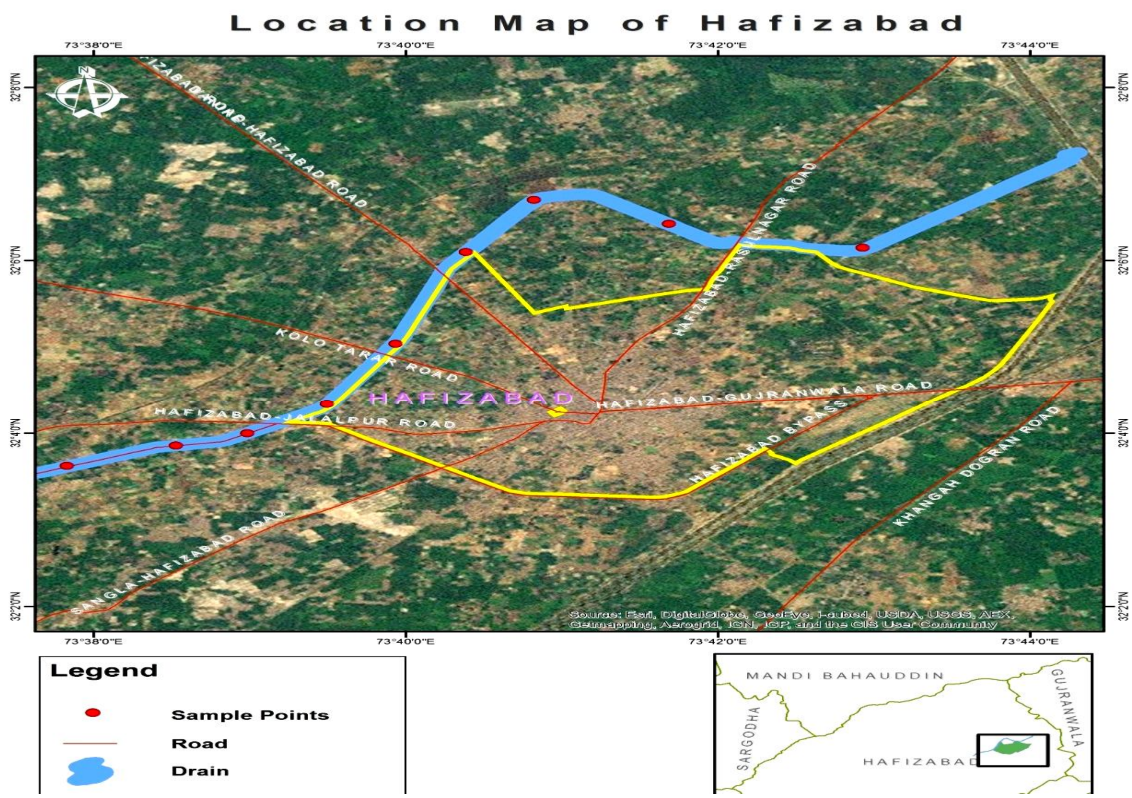


Figure 1. **Location map showing the sampling points**

Sample Collection and Preservation

On each sampling occasion, water samples from all the nine points were collected on the same day with a little time difference. Spot or grab sampling and composite sampling procedures were employed. After sample collection sample preservation is important for retarding biological action, hydrolysis of chemical compounds and complexes and reduction of volatility of constituents. Sample preservation was carried out according to the "Standard Methods for the Examination of Water and Wastewater" [8].

Physico-chemical analysis

A glass thermometer was used to measure temperature of water samples collected from different sampling points of drain. The pH, electrical conductivity and total dissolved solid (TDS) of water samples were measured using handheld pH/electrical conductivity (EC)/TDS meter (Hanna Instruments, model HI 9812). Calcium & hardness was determined by EDTA Titrimetric method, while, the magnesium concentration was determined from the EDTA calcium and hardness titration. For sodium and potassium determination flame photometer (Digital Flame Analyzer Model No. FGA 350) was used. Soxhelt apparatus was used for the extraction and estimation of oil and grease (mg/l) using *n*-hexane as extraction solvent. Carbonyl compounds and cyanides were estimated gravimetrically, whereas, phenols were determined by direct photometric method. Dissolved oxygen (DO) meter (Hanna Instruments model HI 9142) was used on defined sampling sites for the measurement of DO of water samples. Reactor digestion method was used for the determination of chemical oxygen demand (COD) [9], while biological oxygen demand (BOD) was measured by standard BOD 5 method [13]. Suspended solids, sulphate and nitrates were determined by photometric method (HACH Water Analysis Handbook 2002), attenuated radiation method (HACH Water Analysis Handbook 2002), the SPADNS method (HACH Water Analysis Handbook 2002), SulphaVer 4 method (HACH Water Analysis Handbook 2002) and cadmium reduction method (HACH Water Analysis Handbook 2002) using HACH spectrophotometer DR/20/0, respectively. For chloride determination, argentometric titration method was used [10].

Interpolation studies and statistical analysis

The experimental results of different quality parameters studied at nine sampling points of the drain were used and interpolated in GIS environment using kriging techniques to obtain calculated values for the remaining locations of the Drain. It was performed using ArcGIS 9.3 system. The sampling points of under study drain were compared by analysis of variance (ANOVA) using IBM SPSS Statistics (Version 20.0).

Results and Discussions

Different quality parameters of surface water samples collected from nine defined sampling points of drain were analyzed to assess the degradation level of drain surface water. The results were compared with National Environmental Quality Standards (NEQS) guideline data for municipal and industrial effluents.

The trends for different chemical, biological and biochemical parameters of a system are strongly affected by the temperature of the system [11]. The present study indicated that the average temperature of the drain water ranged from 27.0 to 28.5 ^{0}C. These results coincide with the findings of [3], that higher temperature of drain water is probably due to discharge of industrial effluent and domestic sewage into the open drainage. The diverse aquatic life prefers a pH range of 6.5–8.0. Any change in this pH range largely influences the diversity of aquatic life [12]. The average pH values ranged from 7.85 to 8.24. The NEQS guideline value for pH ranges from 6 to 9, which indicates pH in under study drain is in normal range. Similar kind of results for pH and temperature are also documented by [13] while estimating pollution load of rural and urban drains.

The discharge of municipal sewage to streams can change the conductivity of water bodies as sewage comprising chloride, phosphate, nitrate and oil spill lowers the conductivity. High electrical conductivity indicates a larger quantity of dissolved mineral salts [14]. The average Electrical

Conductivity (EC) values ranged from 1475 to 1546 μ siemens/cm. However, the acceptable limit of EC is 1000 μ siemens/cm as per NEQS; hence the present study indicated higher level of electrical conductivity compared to recommended level, which may be due to the heavy sewage dumping and high concentration of ionic constitutions [15]. The hard water has no known impacts on health of organisms, but still is unsuitable for domestic uses [16]. The hardness of water is mainly due to presence of magnesium, calcium and chlorides in the domestic wastes [17]. Water hardness ranged from 194 to 216 ppm. Such kind of variation in hardness are also reported by Hasan *et al.*, [18] while investigating water quality of river Toi in Khyber Pakhtunkhwa.

The municipal agencies analyze trace minerals in wastewater samples to ensure water cleanliness and public health safety [19]. The rock weathering is considered a key source of trace minerals (e.g. Ca, Mg, Na and K), rain water further exaggerate the accumulation of trace minerals in water bodies [20]. The present study indicated that Calcium, Magnesium, Potassium and Sodium concentrations ranged from 71.8 to 81.6, 40.7 to 54.4, 17.9 to 22.3 and 10.7 to 12.5 ppm, respectively, among the selected sampling points. Analysis of variance revealed that magnesium and potassium varied significantly ($p<0.05$), whereas sodium and calcium varied non-significantly ($p>0.05$) at different sampling points of drain (Table 1). The high concentration of oil and grease in wastewater have adverse impacts on living organisms like inhibition of animal and plant growth; carcinogenic and mutagenic to human being and imbalance of ecosystem [21]. Moreover, the higher concentration of oil and grease generally forms a layer over the surface of water, reduces light penetration and photosynthesis [22]. The oil and grease contents of drain water ranged from 14.8 to 20.0 mg/l. The recorded values of oil and grease at all the sampling points were beyond the NEQS limiting value (10 mg/l) for oil and grease, indicating a higher level of oil and grease pollution in surface water of drain in district Hafizabad.

The degradation of natural substance, agricultural practices and industrial activities are the major source of phenolic compounds in the water bodies. Moreover, chlorination of phenol-containing water can lead to the formation of chlorophenols, which have unpleasant taste and are toxic as well [23]. In understudy drain the estimated phenolic and carbonyl compounds in the surface water samples ranged from 3.0 to 6.0 and 0.6 to 0.9 ppm, respectively .Analysis of variance revealed highly significant ($p<0.01$), difference for phenolic and carbonyl compounds at among sampling points of under study drain (Table 1). Cyanide compounds are strictly regulated world over because of their extreme toxicity. Furthermore due to cyanide toxic effects, effluents comprising cyanide compounds cannot be discharged without detoxification into the environment [24]. Cyanide contents varied significantly ($p<0.01$) at different sampling points of understudy drain, ranging between 0.01 to 0.03 ppm. The permissible limit for cyanide is 1 mg/l according to NEQS.

The DO is a key factor to determine the quality of water, and is imperative for aquatic life. The present study revealed highly significant ($p<0.01$) difference for DO among different sampling points of drain. The DO level in drain water ranged from 2.5 to 4.7 ppm. The lower amount of DO in drain water might be due to increased sewage waste inclusion in drain water. The determination of BOD is an essential test to evaluate the relative oxygen requirements of wastewaters, effluents and polluted waters [14]. COD is often used as a measurement of pollutants in natural and waste waters and to assess the strength of waste, such as sewage and industrial effluent waters [25]. Whereas, the measure of COD determines the quantity of organic matter found in water therefore it indirectly indicates the organic pollution in surface water [26]. In understudy drain BOD varied significantly ($p<0.05$) whereas COD varied non-significantly ($p>0.05$) among different sampling points of drain. While the $(BOD)_5$ and COD values ranged from 31.0 to 45.0 and 55.0 to 70.0 ppm in drain water, respectively. The NEQS guideline values for BOD and COD are 80 and 150 ppm, respectively. Interestingly BOD and COD values in drain water were found below NEQS limiting values for these parameters. However continuous increase in the values of these parameters is alarming, which intimates that urgent management should be taken to minimize the pollution causing agents.

Biodiversity holding capacity of water decreases as the TSS rises in water. Moreover light penetration also reduce due to TSS, consequently minimize the process of photosynthesis in water body [22]. Similarly TDS in water bodies enhance the biological and chemical oxygen demand ultimately reducing the level of dissolved oxygen in water [25]. The guideline values as per NEQS for TSS and TDS are 200 and 3500 mg/l, respectively. The TSS and TDS in the surface water at sampling points i.e. 1-9 of drain were found to be varied from 243 to 296 and 1022 to 1248 mg/l, respectively. The higher level of both TSS and TDS in water samples is mainly due to the excessive discharge of domestic and industrial wastes [4].

The agricultural runoff and wastewater from industries and rocks comprising of chlorides are the main sources of chlorides in surface water [27]. The sources of sulphates (SO^{-4}) in the environment are both natural and anthropogenic such as industrial and domestic. The impact of higher level of sulphates in water bodies causes diarrhea and laxative effects [28]. Anaerobic rotting and microbial decay of plants and animals are responsible for nitrogen content in water [29]. Dissolved salts i.e. chlorides, nitrates and sulphates were estimated in the understudy surface water samples and were revealed to be ranged from 297 to 324, 0.10 to 0.30 and 68 to 186 ppm, respectively. The NEQS prescribed limit for chloride is 1000 mg/l. The defined NEQS limiting value for sulphates in waste water is 600 mg/l.

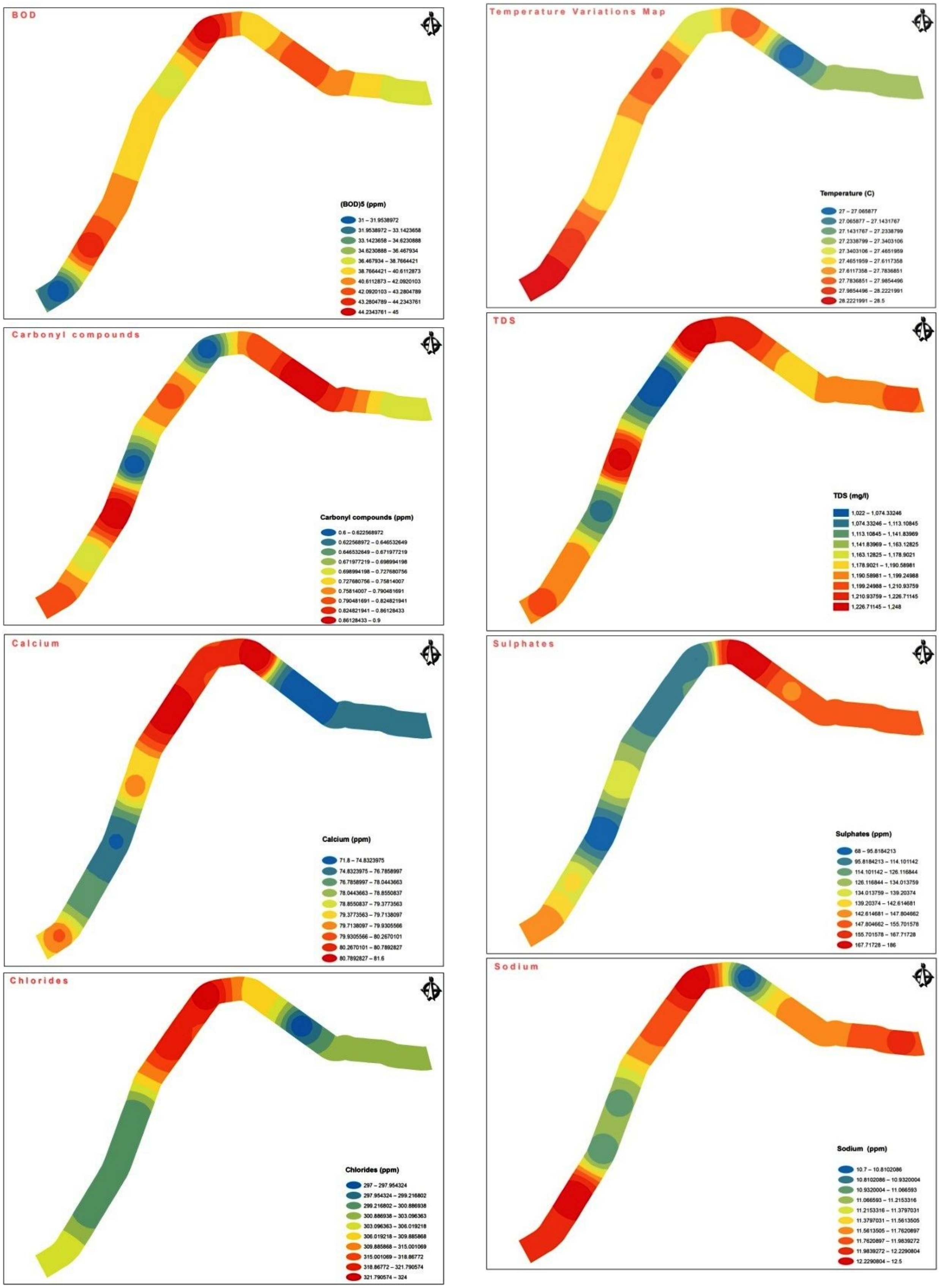
Table 1. **ANOVA and minimum and maximum values of various water quality parameters based on estimated levels.**

Parameter		**SS**	**DF**	**MS**	**F**	***p***	**Min - Max**
Temperature ^{0}C	Between Groups	5.121	8	0.640	0.831	0.587	27.0 - 28.5
	Within Groups	13.867	18	0.770			
	Total	18.987	26				
pH	Between Groups	0.313	8	0.039	0.637	0.737	7.85 - 8.24
	Within Groups	1.105	18	0.061			
	Total	1.417	26				
Electrical Conductivity (μ siemens/cm)	Between Groups	14310.074	8	1788.759	1.690	0.169	1475 - 1546
	Within Groups	19054.667	18	1058.593			
	Total	33364.741	26				
Hardness (ppm)	Between Groups	1294.963	8	161.870	1.661	0.177	194 - 216
	Within Groups	1754.000	18	97.444			
	Total	3048.963	26				
Calcium (ppm)	Between Groups	279.653	8	34.957	2.313	0.067	71.8 - 81.6
	Within Groups	272.073	18	15.115			
	Total	551.727	26				
Magnesium (ppm)	Between Groups	400.823	8	50.103	3.096	0.022	40.7 - 54.4
	Within Groups	291.253	18	16.181			
	Total	692.076	26				
Potassium (ppm)	Between Groups	41.333	8	5.167	2.984	0.026	17.9 - 22.3
	Within Groups	31.167	18	1.731			
	Total	72.500	26				
Sodium (ppm)	Between Groups	10.901	8	1.363	1.246	0.330	10.7 - 12.5

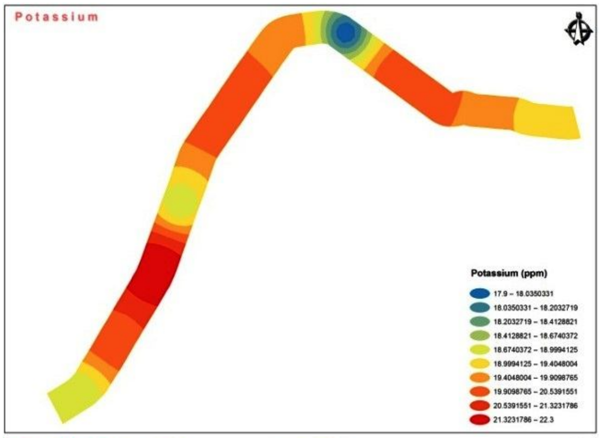
Parameter		SS	DF	MS	F	*p*	Min - Max
	Within Groups	19.687	18	1.094			
	Total	30.587	26				
Oil & Grease(mg/l)	Between Groups	63.370	8	7.921	2.848	0.031	14.8 -20
	Within Groups	50.060	18	2.781			
	Total	113.430	26				
Phenolic Compounds (ppm)	Between Groups	34.697	8	4.337	40.808	0.000	3.0 - 6.0
	Within Groups	1.913	18	0.106			
	Total	36.610	26				
Carbonyl compounds (ppm)	Between Groups	0.360	8	0.045	4.050	0.007	0.6 - 0.9
	Within Groups	0.200	18	0.011			
	Total	0.560	26				
Cyanide (ppm)	Between Groups	0.001	8	0.000	22.500	0.000	0.01 - 0.03
	Within Groups	0.000	18	0.000			
	Total	0.001	26				
Dissolved Oxygen(ppm)	Between Groups	13.783	8	1.723	8.646	0.000	2.5 - 4.7
	Within Groups	3.587	18	.199			
	Total	17.370	26				
(BOD)5 (ppm)	Between Groups	433.613	8	54.202	3.415	0.014	31.0 - 45.0
	Within Groups	285.673	18	15.871			
	Total	719.287	26				
COD (ppm)	Between Groups	565.627	8	70.703	2.016	0.103	55.0 - 70.0
	Within Groups	631.140	18	35.063			
	Total	1196.767	26				
TSS (mg/l)	Between Groups	7926.456	8	990.807	5.549	0.001	243 - 296
	Within Groups	3214.007	18	178.556			
	Total	11140.463	26				
TDS (mg/l)	Between Groups	125167.852	8	15645.981	17.126	0.000	1022 - 1248
	Within Groups	16444.000	18	913.556			
	Total	141611.852	26				
Chlorides (ppm)	Between Groups	2334.000	8	291.750	2.058	0.097	297 - 324
	Within Groups	2552.000	18	141.778			
	Total	4886.000	26				
Nitrates (ppm)	Between Groups	0.123	8	0.015	42.675	0.000	0.10 - 0.30
	Within Groups	0.006	18	0.000			
	Total	0.129	26				
Sulphates (ppm)	Between Groups	31025.667	8	3878.208	68.477	0.000	68 - 186
	Within Groups	1019.440	18	56.636			
	Total	32045.107	26				

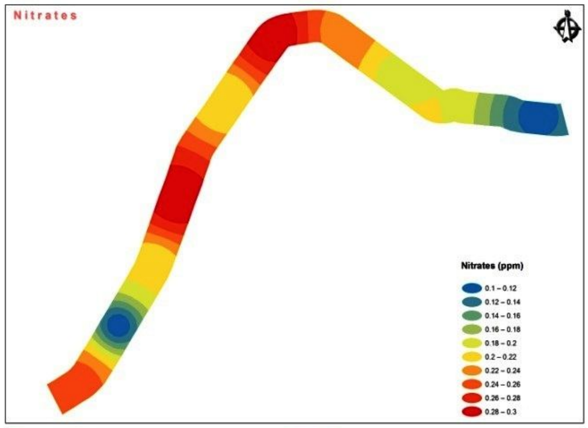
Interpolation studies

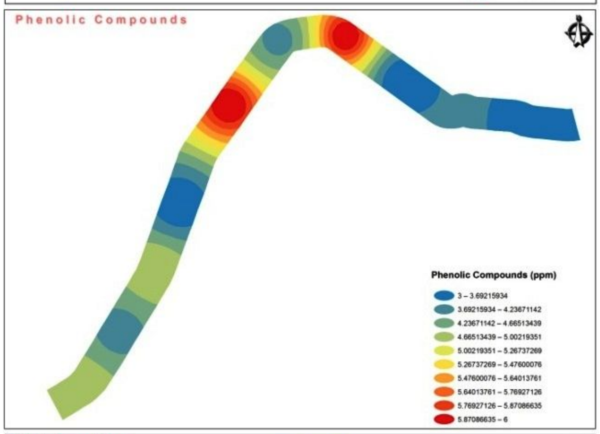
Sampling of the surface water was carried out from nine sampling points along the stretch of drain passing through the territory of Hafizabad city. The procured results were then used to find out water quality along the whole drain i.e. from the sites other than the defined sampling points. The experimental results were interpolated in GIS environment using kriging techniques (Fig 2).

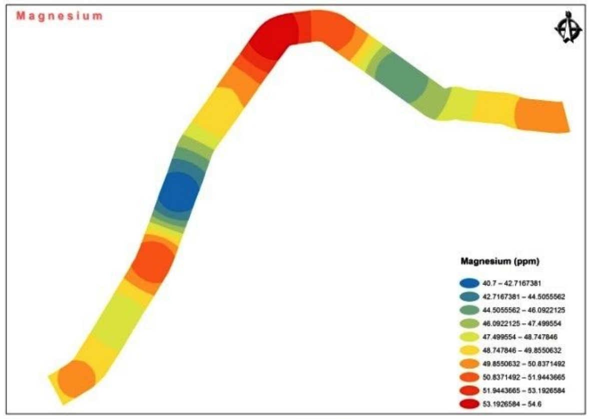


BOD
(BOD)5 (ppm)
31 – 31.9538972
31.9538972 – 33.1423658
33.1423658 – 34.6230888
34.6230888 – 36.467934
36.467934 – 38.7664421
38.7664421 – 40.6112873
40.6112873 – 42.0920103
42.0920103 – 43.2804789
43.2804789 – 44.2343761
44.2343761 – 45
Temperature Variations Map
Temperature (C)
27 – 27.065877
27.065877 – 27.1431767
27.1431767 – 27.2338799
27.2338799 – 27.3403106
27.3403106 – 27.4651959
27.4651959 – 27.6117358
27.6117358 – 27.7836851
27.7836851 – 27.9854496
27.9854496 – 28.2221991
28.2221991 – 28.5
Carbonyl compounds
Carbonyl compounds (ppm)
0.6 – 0.622568972
0.622568972 – 0.646532649
0.646532649 – 0.671977219
0.671977219 – 0.698994198
0.698994198 – 0.727680756
0.727680756 – 0.75814007
0.75814007 – 0.790481691
0.790481691 – 0.824821941
0.824821941 – 0.86128433
0.86128433 – 0.9
TDS
TDS (mg/l)
1,022 – 1,074.33246
1,074.33246 – 1,113.10845
1,113.10845 – 1,141.83969
1,141.83969 – 1,163.12825
1,163.12825 – 1,178.9021
1,178.9021 – 1,190.58981
1,190.58981 – 1,199.24988
1,199.24988 – 1,210.93759
1,210.93759 – 1,226.71145
1,226.71145 – 1,248
Calcium
Calcium (ppm)
71.8 – 74.8323975
74.8323975 – 76.7858997
76.7858997 – 78.0443663
78.0443663 – 78.8550837
78.8550837 – 79.3773563
79.3773563 – 79.7138097
79.7138097 – 79.9305566
79.9305566 – 80.2670101
80.2670101 – 80.7892827
80.7892827 – 81.6
Sulphates
Sulphates (ppm)
68 – 95.8184213
95.8184213 – 114.101142
114.101142 – 126.116844
126.116844 – 134.013759
134.013759 – 139.20374
139.20374 – 142.614681
142.614681 – 147.804662
147.804662 – 155.701578
155.701578 – 167.71728
167.71728 – 186
Chlorides
Chlorides (ppm)
297 – 297.954324
297.954324 – 299.216802
299.216802 – 300.886938
300.886938 – 303.096363
303.096363 – 306.019218
306.019218 – 309.885868
309.885868 – 315.001069
315.001069 – 318.86772
318.86772 – 321.790574
321.790574 – 324
Sodium
Sodium (ppm)
10.7 – 10.8102086
10.8102086 – 10.9320004
10.9320004 – 11.066593
11.066593 – 11.2153316
11.2153316 – 11.3797031
11.3797031 – 11.5613505
11.5613505 – 11.7620897
11.7620897 – 11.9839272
11.9839272 – 12.2290804
12.2290804 – 12.5

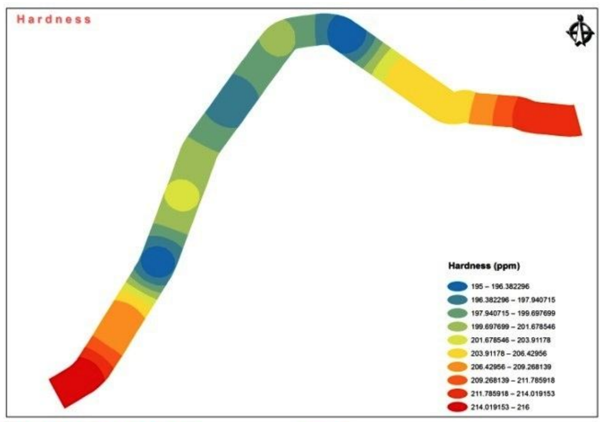

Potassium
Potassium (ppm)
17.9 – 18.0350331
18.0350331 – 18.2032719
18.2032719 – 18.4128821
18.4128821 – 18.6740372
18.6740372 – 18.9994125
18.9994125 – 19.4048004
19.4048004 – 19.9098765
19.9098765 – 20.5391551
20.5391551 – 21.3231786
21.3231786 – 22.3

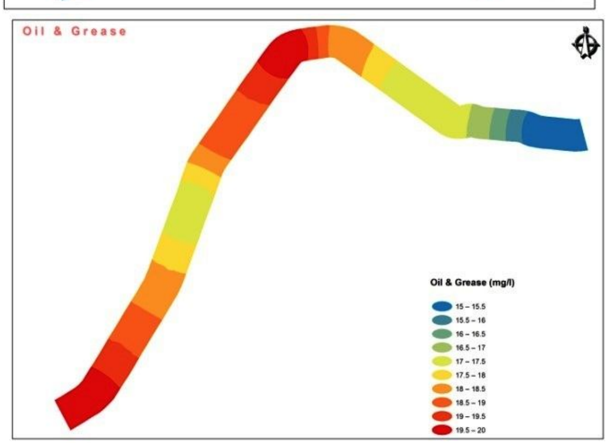

Nitrates
Nitrates (ppm)
0.1 – 0.12
0.12 – 0.14
0.14 – 0.16
0.16 – 0.18
0.18 – 0.2
0.2 – 0.22
0.22 – 0.24
0.24 – 0.26
0.26 – 0.28
0.28 – 0.3

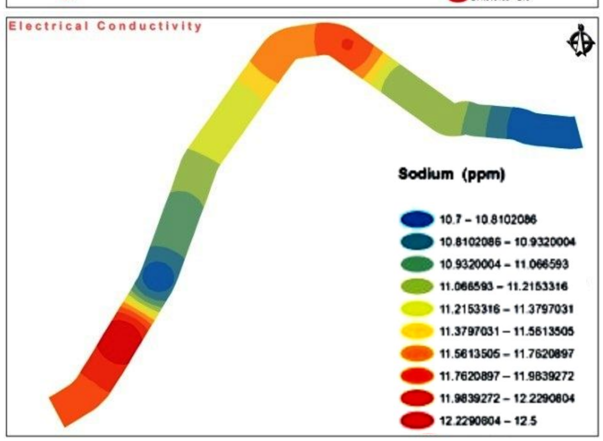

Phenolic Compounds
Phenolic Compounds (ppm)
3 – 3.69215934
3.69215934 – 4.23671142
4.23671142 – 4.66513439
4.66513439 – 5.00219351
5.00219351 – 5.26737269
5.26737269 – 5.47600076
5.47600076 – 5.64013761
5.64013761 – 5.76927126
5.76927126 – 5.87086635
5.87086635 – 6


Magnesium
Magnesium (ppm)
40.7 – 42.7167381
42.7167381 – 44.5055562
44.5055562 – 46.0922125
46.0922125 – 47.499554
47.499554 – 48.747846
48.747846 – 49.8550632
49.8550632 – 50.8371492
50.8371492 – 51.9443665
51.9443665 – 53.1926584
53.1926584 – 54.6


PH Values Map
PH
7.85 – 7.90342887
7.90342887 – 7.94463186
7.94463186 – 7.97640656
7.97640656 – 8.00091041
8.00091041 – 8.01980715
8.01980715 – 8.044311
8.044311 – 8.07608571
8.07608571 – 8.11728869
8.11728869 – 8.17071756
8.17071756 – 8.24


Hardness
Hardness (ppm)
195 – 196.382296
196.382296 – 197.940715
197.940715 – 199.697699
199.697699 – 201.678546
201.678546 – 203.91178
203.91178 – 206.42956
206.42956 – 209.268139
209.268139 – 211.785918
211.785918 – 214.019153
214.019153 – 216


Oil & Grease
Oil & Grease (mg/l)
15 – 15.5
15.5 – 16
16 – 16.5
16.5 – 17
17 – 17.5
17.5 – 18
18 – 18.5
18.5 – 19
19 – 19.5
19.5 – 20


Electrical Conductivity
Sodium (ppm)
10.7 – 10.8102086
10.8102086 – 10.9320004
10.9320004 – 11.066593
11.066593 – 11.2153316
11.2153316 – 11.3797031
11.3797031 – 11.5613505
11.5613505 – 11.7620897
11.7620897 – 11.9839272
11.9839272 – 12.2290804
12.2290804 – 12.5

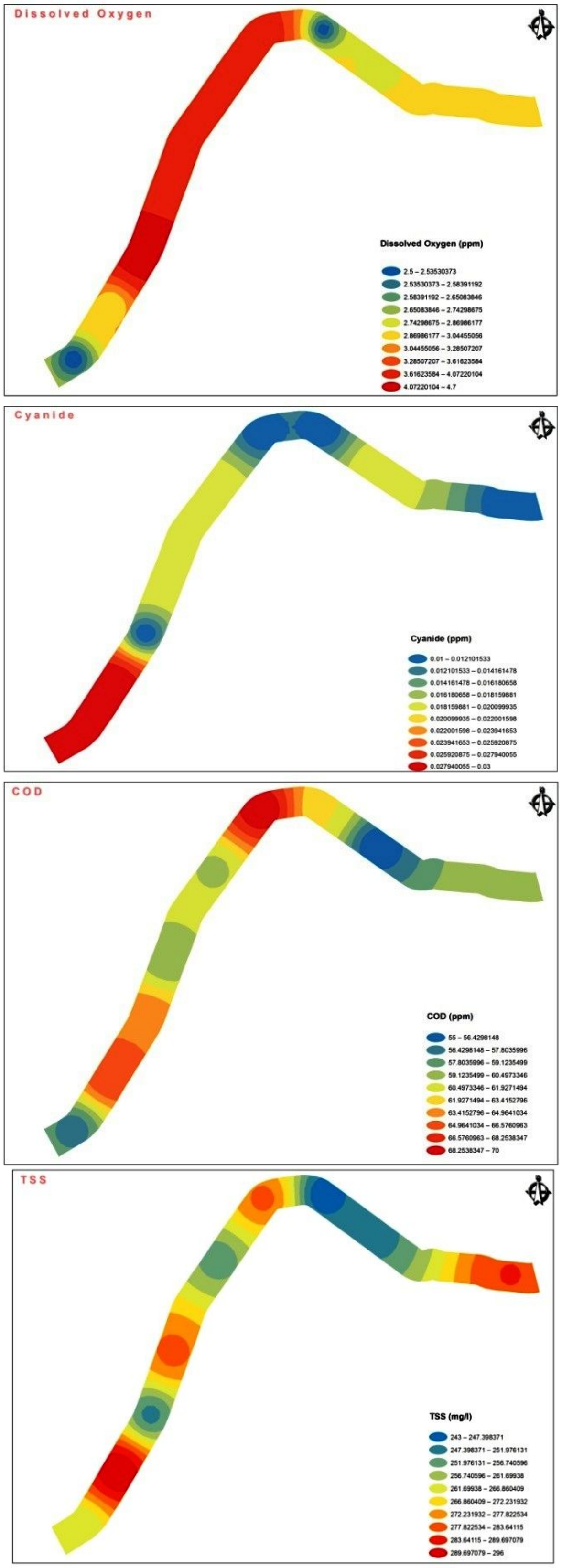


Figure 2. **Interpolated in GIS environment using kriging techniques.**

Conclusion

The present investigation reveals that understudy drain contains various pollutants, which pollute the quality of water. These pollutants mainly enter into drain water by domestic and industrial effluents, and if this addition of waste remains constant, then in near future this drain water will be completely unfit for the use of agricultural purposes as well as a threat to ecosystem. Therefore urgent measures are needed to control pollution level in small water bodies. Although many parameters are in range of NEQS guideline values still, there is considerable need for better understanding of these small water bodies so that they can be managed in an eco-friendly manner.

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