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Comparative physico-chemical characterization and spatial distribution of pollutants in rural and urban drains water

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Abstract

The present study was conducted to compare the pollution level of rural and urban drains water in Dinga, Gujrat, Pakistan. The water samples were collected randomly from five sampling points of rural and urban drains each, and total of 29 physico-chemical parameters were analyzed. The comparison of mean values indicated that urban drain was relatively more polluted compared to rural drain. The highly significant difference ($p<0.01$) was recorded for the levels of pH, biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), an-ionic detergents, sulphates, sulphide, ammonia, chromium, copper, nickel, total toxic metals, zinc, iron and chlorine; while the significant difference ($p<0.05$) was found for grease & oil, fluoride and nickel between rural and urban drain. Furthermore, the physico-chemical parameters varied significantly ($p<0.01$ or $p<0.05$) within different sampling points of each drain. The experimental results of different quality parameters studied in both the drains were interpolated in GIS environment using kriging techniques to obtain calculated values for the remaining locations of the drains. In conclusion, most of the pollutants were in range of NEQS guideline values, but still the risks of increased contamination of water resources cannot be excluded, which may be hazardous for local population. Therefore, there is an urgent need to protect the natural streams from further degradation. These results can be helpful for future management of other polluted drains and small streams in the same eco-region.

Keywords: Drain, pollution, physico-chemical analysis, toxicity

Introduction

In Pakistan, drains are mainly used to collect the industrial and municipal effluents of diverse composition. Hamid *et al*. (2013) reported that waste water of Shahdara drain, Iqbal Town drain, Hudiara drain and others was highly polluted and misfit for irrigation. All the studied parameters (14) were above the permissible limits. Drain waters contain different pollutants including heavy metals, phenols, oil, grease, sulphates, chloride, ammonia, pesticides, total suspended solids (TSS), total dissolved solids (TDS), variable pH, high temperature etc. (Hamid *et al*., 2013; Yadav and Yadav, 2014). These pollutants are harmful for the biological system. For instance, heavy metals interfere with physiological activities of plants such as gaseous exchange, photosynthesis, nutrient absorption, and cause reductions in plant growth, dry matter accumulation and yield. Dietary intake of many heavy metals through consumption of plants has long term detrimental effects on human health (Sharma and Agarwal, 2005). Organic toxic waste (oil and grease (O&G)) causes ecology damages for aquatic organisms (Islam *et al*., 2013) plant, animal and equally mutagenic and carcinogenic for human being (Lan *et al*., 2009). Oils and greases in waters increase BOD and they may float to the surface and harden, causing aesthetically unpleasing conditions. Such polluted water of drains is discharged to surface waters and cause serious contamination of good quality resources.

Pakistan is blessed with adequate ground and surface water resources for drinking, agricultural and other uses. However, the water quality and quantity are under great stress, due to rapid increase in population, urbanization, industrial and agriculture growth, over-exploitation of groundwater resources and unsustainable water consumption practices (Bhanger and Memon, 2008). Pakistan is an agricultural country and its water demands are very high. Due to the water scarcity issues, the wastewaters of city drains are being used for irrigation purposes in different parts of the country without any prior treatment. In Pakistan, the percentage of the wastewater, which is treated before use in irrigation is only 2% (Pay *et al*., 2010). The polluted water affects the agricultural production, biodiversity and human health. The untreated effluents are directly discharged in the drains, from where

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they reach the canals, rivers or the sea and deteriorate water quality (Ayesha, 2012). The polluted water has become a threat to various water usages including drinking, irrigation, and sustenance of aquatic life (Anonymus, 2008). The assessment of water quality is not carried out regularly. The water quality laws and regulations are present in Pakistan. Pakistan Environmental Protection Act 1997 focuses on the protection, conservation, rehabilitation and improvement of the environment, prevention and control of pollution, and promotion of sustainable development. The National Water Policy (Draft), National Environment Policy and National Environmental Quality Standards (NEQS) also exist in Pakistan, but the implementation of laws and regulations is weak (Hashmi *et al*., 2011)

The water of drain, passing from Dinga city and its surrounding rural areas is also being used for irrigation purpose by the farmers. The present study was conducted to evaluate the pollution level of city and rural drains of Dinga for the purpose to check its suitability for irrigation purpose. Pollution level of 29 different wastewater parameters was checked using standard procedures. Principal component analysis (PCA) was applied to estimate the variability in different parameter of rural and city drains. Furthermore point to point pollution level was also estimated.

Materials and Methods

The study was carried out to assess the pollution level and establishment of environmental profile of rural and urban drain (saim nalas) from Dinga (32.6410° N, 73.7243° E), Gujrat, Pakistan, located between Jehlum and Chenab rivers. The grand trunk (GT) road (Rawalpindi to Lahore) is almost 25 km northeast of Dinga city. The rural drain passes from the surrounding rural areas of Dinga city, while the urban drain passes through Dinga city. Both drains are being polluted due to the discharge of domestic and municipal wastes as well as indiscriminate application of agrochemicals. Based on the initial survey, five sampling points were selected randomly for the collection of wastewater samples from each drain (Figure 1).

The wastewater samples were collected in sterile polyethylene bottles from selected points of rural and urban drain**.** The spot or grab sampling procedure was used for collection of water samples. Temperature of the water samples was determined immediately by using glass thermometer. The water samples were acidified with few drops of HNO_3 to make heavy metals available in dissolved form during storage. The collected samples were brought to laboratory and preserved in a refrigerator at 4°C for further physic-chemical analysis. Samples were preserved according to the methods described by Greenberg *et al*. (1992).

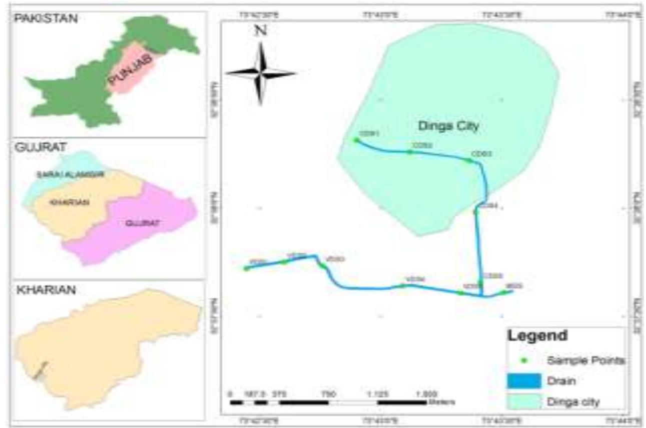


Figure 1: Location map showing the sampling points

Total dissolved solids (TDS) and pH of wastewater samples were measured by using handheld pH/TDS meter (Hanna Instruments, model HI 9812). Chloride content was determined by argentometric titration method (Ahmed, 2000). The solvent extraction method was employed for the determination of oil and grease (mg L^{-1}) using n-hexane as solvent. The chemical oxygen demand (COD) and biological oxygen demand (BOD) were calculated by Reactor digestion method (Jirka and Carter, 1975) and standard BOD 5 method (Greenberg *et al*., 1992), respectively. The measurement of sulfides (S^{2-}) was made by methylene blue method (Hach method # 8131), using HACH DR5000 spectrophotometer as illustrated by HACH Company (2005). However, sulphate concentration was evaluated by using “HACH Spectrophotometer DR/20/0” after calibration (wavelength = 450nm). Total suspended solids (TSS) were calculated gravimetrically by weighing the fraction remaining on a Whatman 934AH glass fiber filter, dried at 105°C and measured (APHA, 2005). Ammonia in water samples was measured by colorimetric method using the indophenol reaction with sodium salicylate and hypochlorite by Flow Injection Analysis Method 4500-P G. Phenolic compounds were measured by flow injection analysis (FIA) with spectrophotometric detection, employing the 4-aminoantipyrine reaction. Anionic detergents were analyzed spectrophotometrically using acridine orange.

Concentration of iron, chlorine and fluoride in water samples was measured photometrically in Spectroquant NOVA 60 (Merck, Germany) using kits provided by Merck and the readings were recorded on automatic computerized system and expressed in mg L^{-1}. Estimation of heavy metals were done by using Atomic Absorption Spectrophotometer (Perkin Elmer Mode 2380). Atomic Absorption

Spectrophotometer was calibrated for each element using standard solution of known concentration before sample injection (Greenberg *et al*., 1992). All the wastewater parameters measured were compared with NEQS limits set for wastewater (NEQS, 2000).

Inverse distance weighted (IDW) raster interpolation technique was used to delineate the location wise distribution of different water pollutants in both drains using spatial analyst module in ArcGIS (version 10.1) software. The sampling points of each water drain were compared by analysis of variance (ANOVA) using IBM SPSS Statistics (Version 20.0). Furthermore, rural and urban drains were compared for level of pollutants by applying T-test using PAST (Version 2.15). Principal component analysis (PCA) was applied to the data using Minitab 17 software, (Minitab TM Inc., USA). Pollutants which were not detected in the wastewater samples were excluded during PCA analysis

Results and Discussion

The present study deals with comparative physico-chemical analysis of water samples collected from rural and urban drains.

Principle component analysis

In PCA, the number of components is equal to the number of variables (Fataei, 2011). As known, PCA is a mathematical transform which is used to explain variance in experimental data (Casillas-Hernandez *et al*., 2006), and to find the correlation between different dependent variables (Li *et al*., 2000). Principal component analysis of city and rural drains showed that both drains varied in composition/pollution load (Figure 2). Scores of city drain samples occupied different ordinal spaces compared to rural drain samples. Percent variability in data explained by first and second component was 65.3 and 6.9%, respectively. Correlation among different variables/components is shown in Table 1. Furthermore, it was found that pollution load of both drains varied with respect to sampling points (Figure 3 and 4).

pH and temperature

Data regarding pH of two drains showed that pH of the drains varied significantly (Table 2). Furthermore, pH was significantly different with sampling points both in rural and urban drains. The average pH of urban drain (8.42±0.068) was higher compared to rural drain (8.02±0.098). However, these results showed that value of pH was within the acceptable range according to NEQS and FAO guidelines. A substantial amount of detergents are used for washing purpose in city (Chaturvedi and Kumar, 2011), their addition to drains may increase the pH of the urban drain water. Aygun and Yilmaz (2010) reported pH of detergent contaminated wastewater as 12.31. In our study detergent concentration in urban drain was found 46% higher compared to rural drain. Dinga city drain also receives the wastewater of small tannery industry (Gujar leather house), marble industry and furniture industry etc. According to Alturkmani (2004), pH of the tannery effluent may range from 11-12. Thus, high pH of the city drain might also be associated with discharge of wastewater of factories/commercial units which contains high amount of basic salts. Mumtaz *et al*. (2009) documented similar results for pH variation, while working on canal water. The variation in drain surface water temperature usually depends on the season, geographic location, sampling time and temperature of effluent entering the drain (Ahipathy and Puttaiah, 2006). Non-significant ($p<0.05$) variation in temperature was observed between rural and urban drains for different sampling points.

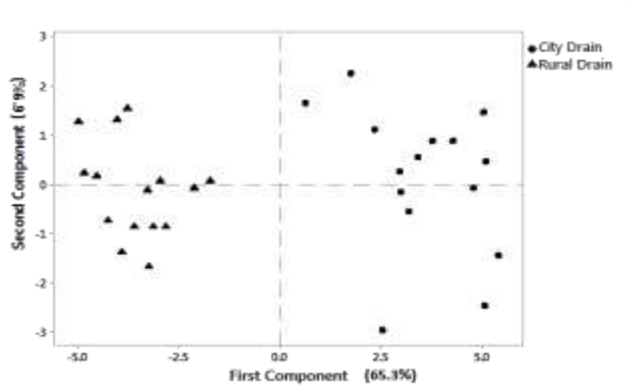


Figure 2: Principal component analysis (PCA) plot of different wastewater parameters (city drain), of city and rural drain. "●" Shows fifteen samples of city drain taken from five different sampling points, whereas "▲" shows fifteen samples of rural drain taken from five different sampling points

Biological oxygen demand (BOD) and chemical oxygen demand (COD)

The BOD and COD of water indicated the risk of oxygen depletion due to degradation of organic matter (Eriksson *et al*., 2002). T-test revealed statistically significant ($p<0.01$) difference between BOD and COD values of rural and urban drains (Table 2). The results showed high values of BOD and COD in water samples taken from urban drain compared to rural drain (Table 2). Biological oxygen demand of urban and rural drains was 81.27±1.11 and 56.64±0.79 mg L^{-1}, respectively. The BOD of urban drain was slightly higher than the permissible limit. Hamid *et al*. (2013) also reported that Shahdara drain, Iqbal

Table 1: Eigen value and percentage of variance explained by each of the 22 principal components (PCs) for wastewaters drain studied variables

Principal components	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11
Eigena analysis of correlation coefficient matrix											
Eigenvalue	14.356	1.509	1.465	1.080	0.753	0.579	0.523	0.446	0.379	0.259	0.191
% total variance explained	0.653	0.069	0.067	0.049	0.034	0.026	0.024	0.020	0.017	0.012	0.009
% Cumulative	0.653	0.721	0.788	0.837	0.871	0.897	0.921	0.941	0.959	0.970	0.979
Rotated factor correlation coefficients											
Variable											
pH	0.184	-0.287	-0.257	0.206	-0.060	0.489	0.160	0.024	0.410	-0.136	0.276
Temperature	0.047	0.359	-0.270	0.744	-0.111	0.135	-0.125	-0.223	0.085	0.008	-0.201
Biochemical Oxygen Demand (BOD5)	0.250	0.027	0.090	-0.033	-0.272	0.159	-0.022	-0.027	0.145	-0.065	-0.052
Chemical Oxygen Demand (COD)	0.254	-0.000	0.082	-0.069	-0.185	0.126	-0.112	0.019	0.096	-0.092	-0.131
Total Suspended Solids (TSS)	0.236	0.094	-0.132	-0.112	0.300	-0.067	0.052	-0.066	0.061	0.152	0.398
Total dissolved Solids (TDS)	0.252	0.104	0.053	-0.172	0.122	0.105	-0.078	-0.019	0.094	0.081	0.069
Grease & Oil	0.209	0.206	0.237	-0.010	0.313	0.267	-0.143	-0.107	0.397	0.031	-0.019
Phenolic Compounds	0.187	-0.370	-0.035	0.152	-0.199	-0.218	0.574	0.057	0.084	0.129	-0.081
Chloride	0.095	0.484	-0.355	-0.345	-0.422	0.016	0.136	0.213	0.198	-0.204	0.081
Fluoride	0.210	-0.336	-0.102	0.064	-0.107	-0.086	-0.405	-0.055	0.229	-0.159	0.375
An-Ionic Detergents as MBAs	0.236	-0.160	0.107	0.099	0.263	0.072	0.142	-0.065	0.161	0.070	-0.011
Sulphate	0.237	0.082	0.285	-0.072	0.050	0.142	-0.079	0.039	0.176	0.152	-0.223
Sulphide	0.215	-0.148	-0.106	-0.086	-0.113	-0.337	-0.205	0.057	0.587	0.235	-0.298
Ammonia	0.255	0.020	0.125	-0.077	-0.072	0.112	-0.026	0.056	0.133	-0.129	-0.180
Chromium	0.217	0.106	0.145	-0.042	-0.305	-0.035	0.239	-0.519	0.034	0.262	0.234
Copper	0.214	0.116	-0.045	0.004	0.134	-0.516	-0.068	-0.435	0.092	-0.448	0.047
Nickel	0.208	0.228	-0.163	0.236	0.189	-0.306	0.065	0.322	0.060	0.354	-0.001
Silver	0.235	0.188	-0.051	0.029	0.117	-0.001	0.051	0.355	0.150	0.071	0.315
Total toxic metals	0.231	-0.078	-0.074	0.058	0.277	-0.034	0.207	0.218	0.096	-0.548	-0.239
Zinc	0.060	-0.150	-0.663	-0.329	0.224	0.191	-0.061	-0.282	0.234	0.212	-0.306
Arsenic	0.255	0.045	0.122	-0.058	-0.075	0.045	0.159	-0.067	0.078	0.002	-0.260
Chlorine	0.224	-0.209	-0.022	0.093	-0.249	-0.077	-0.442	0.221	0.035	0.098	-0.013
Eigen analysis of correlation coefficient matrix											
Eigenvalue	0.138	0.109	0.063	0.058	0.043	0.023	0.010	0.008	0.004	0.002	0.002
% total variance explained	0.006	0.005	0.003	0.003	0.002	0.001	0.000	0.000	0.000	0.000	0.000
% Cumulative	0.985	0.990	0.993	0.996	0.998	0.999	0.999	1.000	1.000	1.000	1.000

Rotated factor correlation coefficients											
Variable	**PC12**	**PC13**	**PC14**	**PC15**	**PC16**	**PC17**	**PC18**	**PC19**	**PC20**	**PC21**	**PC22**
pH	0.169	-0.032	0.070	-0.228	0.069	0.227	0.252	0.115	-0.146	0.043	0.016
Temperature	-0.216	-0.071	-0.149	-0.029	0.060	-0.094	-0.096	-0.003	0.038	0.035	-0.018
Biochemical Oxygen Demand (BOD5)	0.014	0.100	0.166	0.161	0.034	0.375	-0.075	-0.408	0.083	-0.157	-0.624
Chemical Oxygen Demand (COD)	0.106	0.080	-0.031	0.079	0.224	0.325	-0.276	0.409	0.415	-0.268	0.399

Rotated factor correlation coefficients											
Variable	**PC12**	**PC13**	**PC14**	**PC15**	**PC16**	**PC17**	**PC18**	**PC19**	**PC20**	**PC21**	**PC22**
pH	0.169	-0.032	0.070	-0.228	0.069	0.227	0.252	0.115	-0.146	0.043	0.016
Temperature	-0.216	-0.071	-0.149	-0.029	0.060	-0.094	-0.096	-0.003	0.038	0.035	-0.018
Biochemical Oxygen Demand (BOD5)	0.014	0.100	0.166	0.161	0.034	0.375	-0.075	-0.408	0.083	-0.157	-0.624
Chemical Oxygen Demand (COD)	0.106	0.080	-0.031	0.079	0.224	0.325	-0.276	0.409	0.415	-0.268	0.399
Total Suspended Solids (TSS)	-0.362	0.007	-0.121	-0.439	-0.031	0.216	-0.256	-0.335	0.135	-0.086	0.169
Total dissolved Solids (TDS)	-0.160	0.128	-0.181	-0.129	-0.055	-0.030	-0.183	0.614	-0.180	0.305	-0.458
Grease & Oil	0.318	0.347	-0.174	0.096	-0.042	-0.375	-0.136	-0.199	0.085	-0.167	-0.012
Phenolic Compounds	0.036	0.284	-0.453	-0.006	0.053	-0.192	-0.022	-0.039	0.140	-0.012	-0.071
Chloride	-0.227	0.173	-0.034	0.109	-0.146	-0.176	0.155	-0.009	0.060	0.004	0.090
Fluoride	-0.190	0.251	0.204	0.134	0.280	-0.406	0.069	-0.010	-0.083	-0.096	0.039
An-Ionic Detergents as MBAs	-0.460	-0.038	0.113	0.617	-0.280	0.128	0.107	0.035	0.112	0.154	0.131
Sulphate	-0.182	-0.105	-0.095	-0.276	0.093	-0.092	0.720	0.014	0.159	-0.162	0.001
Sulphide	-0.166	-0.274	0.076	-0.086	0.311	-0.062	-0.129	-0.020	0.028	0.001	-0.137
Ammonia	0.119	0.020	0.045	-0.065	0.213	-0.011	-0.061	-0.298	-0.004	0.775	0.256
Chromium	0.204	-0.296	0.345	-0.057	-0.180	-0.252	-0.051	0.092	0.113	0.029	0.039
Copper	0.204	0.026	-0.222	0.051	-0.004	0.265	0.278	0.041	-0.067	0.037	-0.020
Nickel	0.262	0.364	0.450	-0.015	-0.006	0.140	0.143	0.101	-0.028	0.031	0.027
Silver	0.242	-0.543	-0.280	0.349	0.248	-0.068	-0.006	-0.031	-0.101	-0.070	-0.043
Total toxic metals	-0.001	-0.232	0.302	-0.210	-0.204	-0.284	-0.165	0.044	0.159	-0.131	-0.118
Zinc	0.178	-0.031	-0.034	0.134	-0.025	-0.045	0.058	-0.053	0.032	-0.028	-0.004
Arsenic	-0.105	0.035	0.036	-0.002	0.008	0.044	-0.130	-0.047	-0.784	-0.293	0.260
Chlorine	0.165	-0.091	-0.216	-0.087	-0.683	0.041	-0.018	-0.066	-0.040	0.021	0.097

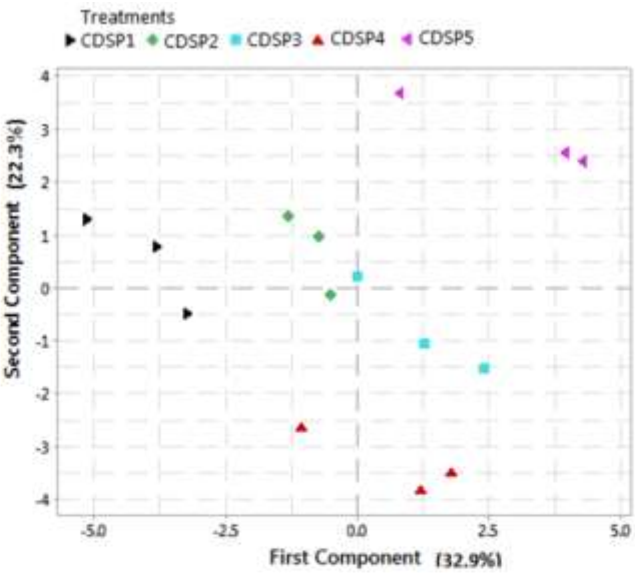


Figure 3: PCA plot of different wastewater parameters (city drain), taken from five different points of city drain

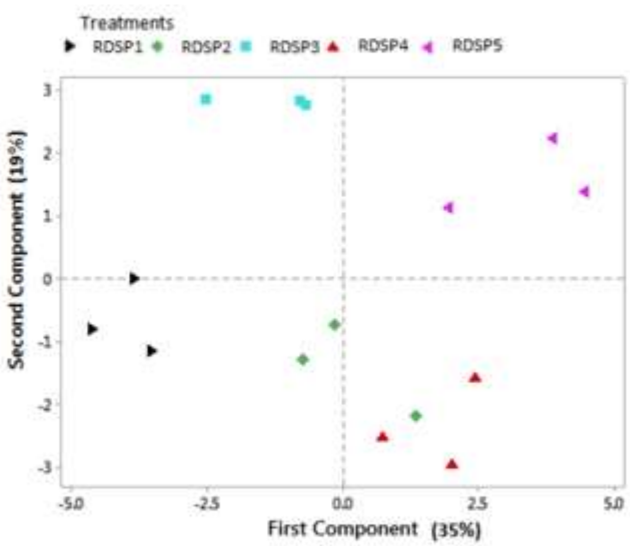


Figure 4: PCA plot of different wastewater parameters (city drain), taken from five different points of rural drain

Town drain, Hudiara drain and others had high values of BOD than NEQS limit. The high value of BOD in urban drain is might be due to direct discharge of sewage waste and industrial organic waste. Furthermore, addition of oils and greases to receiving waters increases BOD and they may float to the surface and harden, causing aesthetically unpleasing conditions. In our study, high values for oil and grease were observed compared to rural drain, which might had contributed to high values of BOD in urban drains. Highest average COD value (112.53±1.558 mg L^{-1}) was also recorded in urban drain. COD varied from 74.60 - 83.90 mg L^{-1} and 104.00 - 121.00 mg L^{-1} in rural and urban drains, respectively at different sampling points. Analysis of variance showed that BOD and COD variation among different sampling points in rural and urban drain was also highly significant (*p<0.01*). The mean values of BOD and COD in both drains were in range of NEQS limiting values (Table 2).

Total suspended solids (TSS) and total dissolved solids (TDS)

Statistically significant (*p<0.01*) difference in TSS and TDS content was found between rural and urban drains (Table 2). The average values of TSS and TDS were higher in urban drain (43.47±1.502 and 367.27±3.322 mg L^{-1}) than rural drain (29.93±1.102 and 303.33±2.718 mg L^{-1}). However, both TSS and TDS were under permissible limits. Furthermore, TSS and TDS varied significantly (*p<0.01*) among different sampling points in rural and urban drains. The higher values of TSS and TDS in urban drain were might be due to higher run off from bathing Ghats and garbage dumping sites in urban areas compared to rural areas (Rai *et al*., 2011).

Oil and grease and phenolic compounds

Oil and grease usually form a layer over the water surface, which prevents the penetration of sunlight, thus hinders the photosynthesis in aquatic plants (Eaton and AWWA 2005). It was observed that oil and grease content differed significantly (*p<0.05*) between rural and urban drain. The content of oil and grease in rural and urban drains were 6.37±0.222 and 8.16±0.115 mg L^{-1}, respectively (Table 2). The sources of oil and grease in drain can be traced to domestic, industrial and commercial wastewater (Hamid *et al*., 2013). Laundries are considered among the most common industries releasing oil and grease (WWF). Automobile factories, vehicle repairing units, motor garage, asphalt road constructions produced oil and grease (Hossain *et al*., 2006). Oil and grease from such sources may reach the city drains through runoff and other sources, resulting in high oil and grease content than rural drains. Moreover, significant difference was found for oil and grease content among different sampling points of rural (*p<0.01*) and urban (*p<0.05*) drain. It is evident from the present results that average oil and grease (mg L^{-1}) of the rural and urban drain lies within NEQS limits for oil and grease value. The phenolic compounds in the water environment can arise from degradation of natural substance, industrial activities and agricultural practices. These compounds, especially chlorinated, may be life threatening to humans even at low concentrations (Daviá and Gnudi, 1999). The phenolic content of both drains was under permissible limits recommended by NEQS as 0.1 mg L^{-1}.

Anionic detergents

Industrial facilities use detergents to clean machinery. Soap manufacturers and households also discharge anionic detergents into the surface water. These types of discharges caused significant environmental pollution problems (Schramm *et al*., 2003). In this study, anionic detergents as MBAs were detected both in city and rural drains (Table 2). Their content differed significantly ($p<0.01$) between rural and urban drains (Table 3). For detergents, maximum average value (8.20±0.287 mg L^{-1}) was measured in urban drain with range (6.50-9.90 mg L^{-1}) and minimum mean value was measured in rural drain (5.61±0.189 mg L^{-1}) with range (4.80-6.70 mg L^{-1}).

Table 2: Mean values comparison of different physico-chemical parameters and t-test for water samples collected from rural and urban drain. Minimum and maximum values are in parenthesis

Parameter	Rural drain	Urban drain	t value	p value	NEQS limiting value
	Means±SE	Means±SE			
pH	8.02±0.098(7.40-8.80)	8.42±0.068 (8.00-8.90)	-4.017	0.020*	6.5-8.5
Temperature $^{0}C^{*}$	28.90±0.366 (27.00-31.00)	29.20±0.405 (27.00-31.50)	-1.588	0.148 NS	=40^{0}C
BOD (mg L^{-1})	56.64±0.788 (51.40-61.80)	81.27±1.110 (72.30-87.10)	-12.59	0.000**	80
COD (mg L^{-1})	78.99±0.740 (74.60-83.90)	112.53±1.558 (104.00-21.00)	-10.91	0.000**	150
TSS (mg L^{-1})	29.93±1.102 (23.00-36.00)	43.47±1.502 (35.00-54.00)	-4.628	0.010**	200
TDS (mg L^{-1})	303.33±2.718 (286.0-319.0)	367.27±3.322 (345.00-84.00)	-7.698	0.002**	3500
Grease and Oil (mg L^{-1})	6.37±0.222 (5.10-7.90)	8.16±0.115 (7.50-9.00)	-3.286	0.030*	10
Phenols (mg L^{-1})	0.03±0.003 (0.01-0.04)	0.04±0.002 (0.03-0.06)	-2.59	0.078 NS	0.1
Chloride (mg L^{-1})	70.73±1.728 (62.0-81.0)	75.93±1.769 (63.00-86.00)	-0.8487	0.444 NS	1000
Fluoride (mg L^{-1})	0.18±0.007 (0.13-0.21)	0.25±0.013 (0.16-0.32)	-3.742	0.020*	10
Detergents as MBAs (mg L^{-1})	5.61±0.189 (4.80-6.70)	8.20±0.287 (6.50-9.90)	-4.743	0.009**	20
Sulphate (mg L^{-1})	111.27±4.486 (84.0-135.0)	188.20±1.547 (180.0-980.0)	-8.506	0.001**	600
Sulphide (mg L^{-1})	0.02±0.001 (0.01-0.02)	0.03±0.002 (0.02-0.04)	-6	0.004**	1
Ammonia (mg L^{-1})	0.41±0.023 (0.30-0.60)	3.36±0.092 (2.80-3.90)	-19.13	0.000**	40
Chromium (mg L^{-1})	0.01±0.001 (0.01-0.02)	0.06±0.005 (0.03-0.09)	-7.203	0.002**	1
Copper (mg L^{-1})	0.13±0.003 (0.11-0.15)	0.17±0.006 (0.13-0.21)	-5.25	0.006**	1
Nickel (mg L^{-1})	0.01±0.002 (0.01-0.03)	0.03±0.002 (0.01-0.04)	-3.5	0.025*	1
Total toxic metals mg L^{-1}	0.02±0.001 (0.01-0.02)	0.04±0.003 (0.02-0.06)	-10.61	0.000**	2
Zinc (mg L^{-1})	0.03±0.003 (0.02-0.05)	0.07±0.004 (0.04-0.09)	-8.552	0.001**	5
Arsenic (mg L^{-1})	0.007±0.000 (0.00-0.01)	0.008±0.000 (0.00-0.01)	-1.2	0.296 NS	1
Iron (mg L^{-1})	0.60±0.013 (0.51-0.69)	1.25±0.012 (1.15-1.32)	-23.76	0.000**	8
Chlorine (mg L^{-1})	0.20±0.014 (0.10-0.30)	0.39±0.027 (0.20-0.60)	-4.06	0.015**	1

Chlorides and fluorides

Chlorides may get into surface water from several sources, including rocks containing chlorides, agricultural runoff and wastewater from industries (APHA, 1992). The average values of chlorides in rural and urban drains were 70.73±1.728 and 75.93±1.769 mg L^{-1}, respectively (Table 2). Chloride content did not vary significantly between urban and rural drains, and its value was under permissible limits. Aquatic animals take fluoride ions directly from water (Gonzalo and Camargo, 2012). Fluoride can cause many adverse effects on the behavior and survival of sensitive aquatic organisms (Alonso and Camargo, 2011). The average values of fluorides in rural and urban drain were 0.18±0.007 and 0.25±0.013 mg L^{-1}, respectively. Moreover, analysis of variance illustrated that chlorides and fluorides varied significantly ($p < 0.01$) from point to point in rural as well as urban drain.

Sulphates and sulphides

Sulphates are found appreciably in all natural waters, particularly those with high salt contents. Besides industrial pollution and domestic sewage, biological oxidation of reduced sulphure species also adds to sulphate content.

High sulphate concentration present in water of drainage caused laxative effects and diarrhea (Guru, 2003). The toxicity of sulphide to different forms of life is well known (Vaquer-Sunyer and Duarte, 2010; Caliendo *et al.*, 2010). Similarly, the decomposition of organic matter from industrial wastes as well as the bacterial reduction of sulphate resulted in the release of sulphide into waste water (Leeden *et al.*, 1990). Statistically significant ($p<0.01$) sulphates and sulphides difference was found between rural and urban drains. Data in Table 2 showed that average sulphate content was higher in urban drain (188.20±1.547 mg L^{-1}) than rural drain (111.27±4.486 mg L^{-1}). Maximum average value of sulphide was also measured in rural drain (0.03±0.002 mg L^{-1}). Analysis of variance revealed that sulphates varied significantly (p<0.01), whereas no significant variation was observed on the average sulphide content among different sampling points in rural as well as urban drain. The sulphate and sulphide contents of rural and urban drain were in range of NEQS limiting value of sulphates and sulphides.

Ammonia and chlorine

The presence of ammonia is an evidence of sewage inflow to a water body (Janakiraman *et al.*, 2012). Statistically significant ($p<0.01$) difference in ammonia contents was found between rural and urban drains. Average ammonia contents in rural and urban drains were 0.41±0.023 and 3.36±0.092 mg L^{-1}, respectively (Table 2). Analysis of variance indicated that ammonia varied significantly ($p<0.01$) among different sampling points of urban drain, whereas non-significantly ($p>0.05$) among the different sampling points of rural drain. The ammonia concentration in rural and urban drain was in the range of NEQS guideline value of ammonia. Maximum average value of chlorine was found in urban drain 0.39±0.027 mg L^{-1}, followed by rural drain 0.20±0.014 mg L^{-1}. Analysis of variance showed that chlorine variation among different sampling points was non-significant ($p>0.05$) in rural drain whereas in urban drain variation was statistically significant ($p<0.01$).

Table 3: Analysis of variances for different physico-chemical parameters of water samples collected from rural and urban drain of Dinga

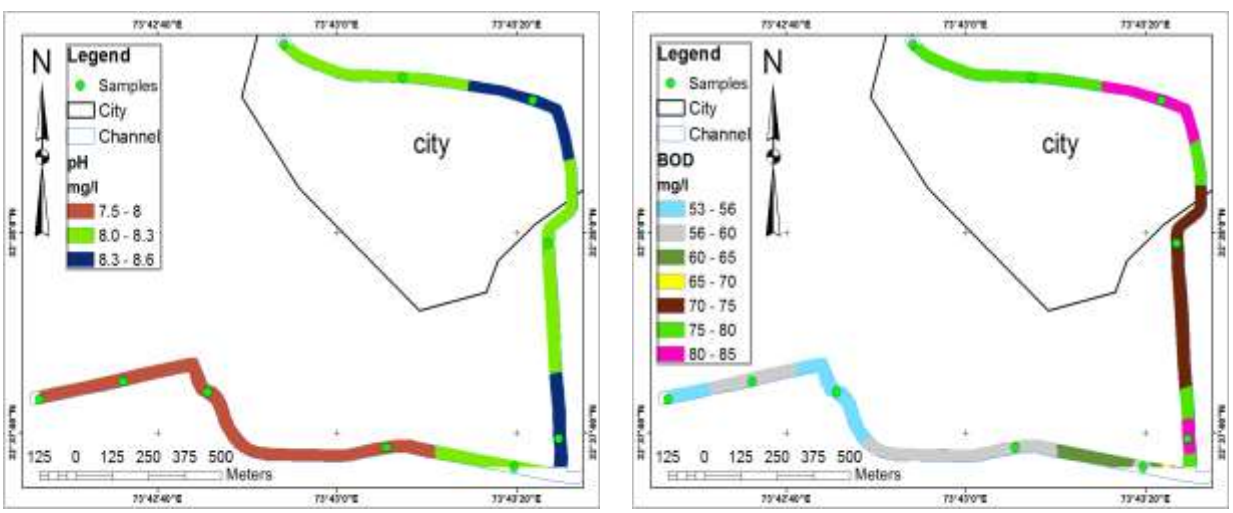
	Rural drain				**Urban drain**			
Parameter	**Sum of square**	**Mean square**	**F value**	***p* value**	**Sum of square**	**Mean square**	**F value**	***p* value**
pH	1.37	0.341	5.315	.015**	0.657	0.164	5.359	.014**
Temperature ^{0}C*	1.43	0.358	0.134	.966^{NS}	0.9	0.225	0.067	.990^{NS}
BOD (mg L^{-1})	103.01	25.752	9.403	.002**	215.98	53.995	12.588	.001**
COD (mg L^{-1})	109.3	27.326	49.03	.000**	473.07	118.267	32.255	.000**
TSS (mg L^{-1})	236.93	59.233	32.907	.000**	408.4	102.1	15.628	.000**
TDS (mg L^{-1})	1493.33	373.333	64.368	.000**	2188.27	547.067	42.518	.000**
Grease and Oil (mg L^{-1})	9.48	2.369	25.938	.000**	1.82	0.456	4.78	.020*
Phenols (mg L^{-1})	0.001	0	5.75	.011*	0.001	0	7.25	.005*
Chloride (mg L^{-1})	588.27	147.067	38.034	.000**	616.27	154.067	37.885	.000**
Fluoride (mg L^{-1})	0.008	0.002	7.566	.004**	0.033	0.008	39.468	.000**
Detergents as MBAs (mg L^{-1})	7.16	1.789	55.917	.000**	15.98	3.995	29.813	.000**
Sulphate (mg L^{-1})	416.93	104.233	179.7	.000**	461.73	115.433	28.385	.000**
Sulphide (mg L^{-1})	0	0	2.167	.147^{NS}	0	0	0.542	.709^{NS}
Ammonia (mg L^{-1})	0.049	0.012	2.056	.162^{NS}	1.46	0.366	11.67	.001**
Chromium (mg L^{-1})	0	0	2.167	.147^{NS}	0.003	0.001	6.5	.028*
Copper (mg L^{-1})	0.002	0	6.85	.006**	0.005	0.001	4.566	.023*
Nickel (mg L^{-1})	0	0	0.571	.690^{NS}	0	0	1.15	.388^{NS}
Total toxic metals (mg L^{-1})	0	0	1.167	.382^{NS}	0	0	0.794	.555^{NS}
Zinc (mg L^{-1})	0.001	0	7.7	.004**	0.002	0.001	14.333	.000**
Arsenic (mg L^{-1})	0	0	4.625	.024**	0	0	2.125	.152^{NS}
Iron (mg L^{-1})	0.029	0.007	10.037	.002**	0.025	0.006	10.682	.001**
Chlorine (mg L^{-1})	0.013	0.003	1.25	.351^{NS}	0.11	0.028	5.929	.010**

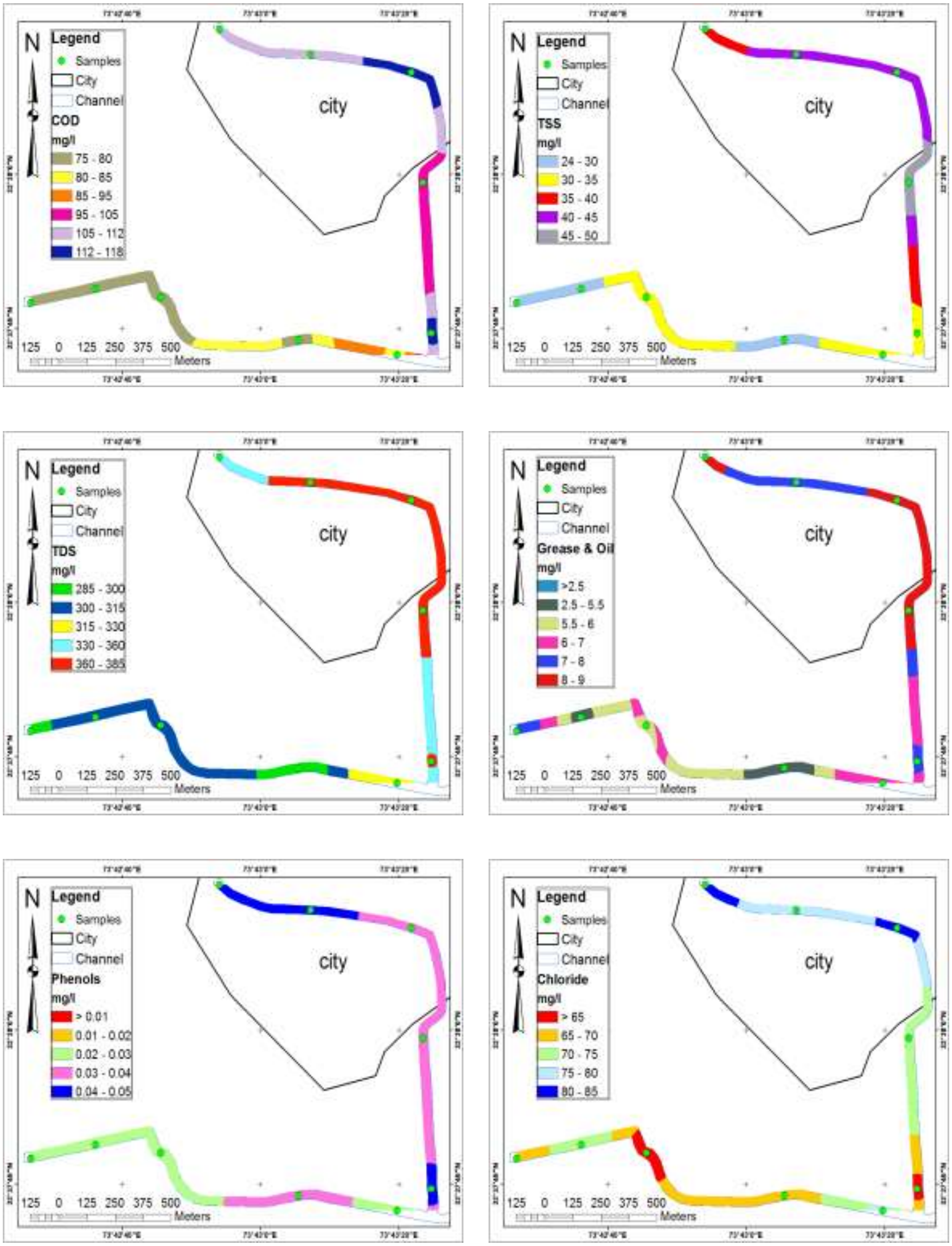
Heavy metals

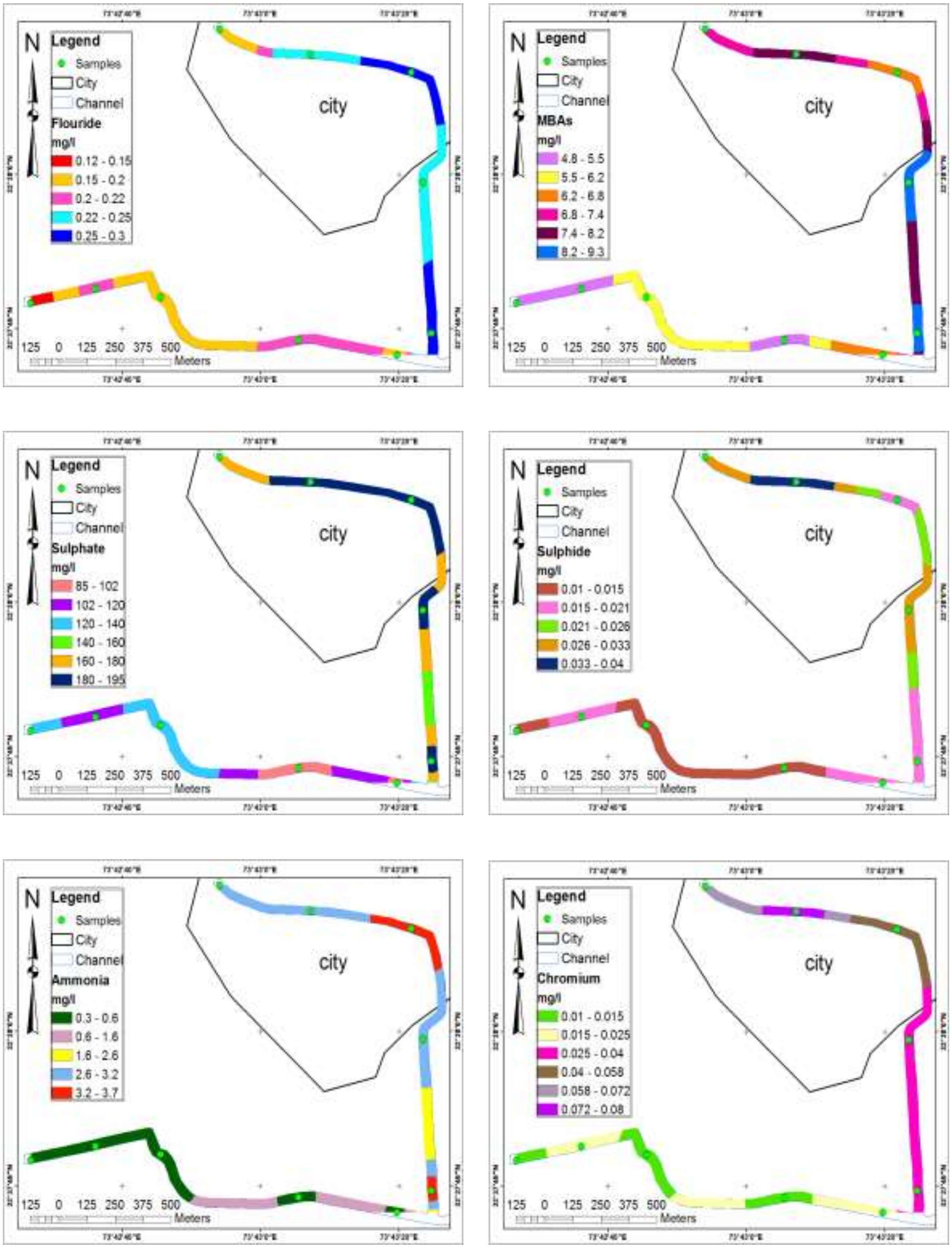
The heavy metals are of special interest among trace elements, which cause various health hazards (Lokhande *et al*., 2011). The excessive accumulation of heavy metals in agricultural soils through wastewater irrigation, not only result in soil contamination, but also leads to elevated heavy metal uptake by crops, and thus affects food quality (Muchuweti *et al*., 2006). The experimental data on heavy metal contents in water samples collected from rural and urban drains are presented in Table 2. It was found that urban drain had high heavy metal pollution compared to rural drain. However, concentration of different heavy metals in rural and urban drain samples was under the permissible limits. There was huge difference in Cr concentration of rural and urban drains. The average values for chromium in rural and urban drains were 0.01±0.001 and 0.06±0.005 mg L^{-1}, respectively. Chromium variation among different sampling points of rural drain was statistically non-significant ($p>0.05$), whereas among the sampling points of urban drain variation was statistically significant ($p<0.05$). Significant variation was observed in copper content among sampling points in rural and urban drains. The average copper contents in rural and urban drain were 0.13±0.003 and 0.17±0.006 mg L^{-1}, respectively. Furthermore, average nickel contents in rural and urban drain were 0.01±0.002 and 0.03±0.002 mg L^{-1}, and average total toxic metals were 0.02±0.001 and 0.04±0.003 mg L^{-1}, respectively. Zinc and iron varied significantly ($p<0.01$) among different sampling points in rural and urban drain. The highest average zinc (0.07±0.004 mg L^{-1}) and iron (1.25±0.012 mg L^{-1}) contents were found in urban drain. Arsenic varied significantly in rural drain and non-significantly in urban drain among different sampling points. Maximum average value of arsenic (0.008±0.000) mg L^{-1} was found in urban drain. Furthermore, chromium, copper, nickel, total toxic metals, zinc and iron contents differed significantly ($p<0.01$) between rural and urban drain. During present study no cyanide, mercury, selenium, silver, barium, manganese and boron were detected in rural and urban drain surface water samples.

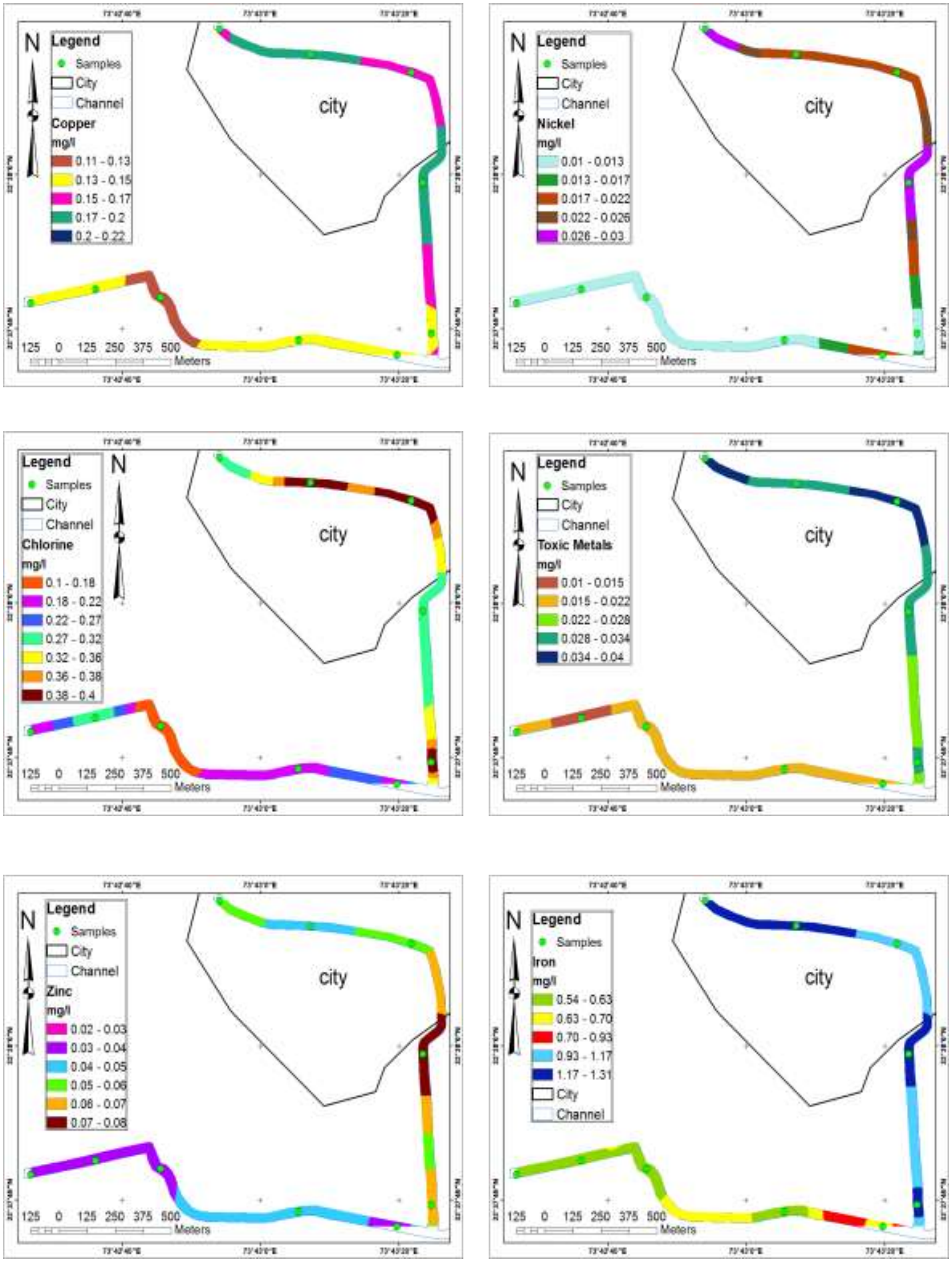
Geostatistical studies are considered imperative to predict pollutant levels for the un-sampled areas. The process is conducted by determining the spatial correlations between estimated and sampled points and by minimizing the variance of estimation error (Zamani-Ahmadmahmoodi *et al*., 2013). An interpolation technique (kriging) gives unbiased, linear estimate of a regionalized variable for areas that have not been sampled (Cinnirella *et al*., 2005). Spatial distribution of pollutants in both drains water was estimated by applying kriging interpolation technique using Geographical Information System (ArcGIS 10.1). Local variant of inverse distance weighting (IDW) was employed to interpolate the data. Interpolation maps to predict the value of various pollutants from un-sampled areas are presented in figure 5.

Figure 5: Interpolated in GIS environment using kriging techniques




Legend
Samples
City
Channel
COD
mg/l
75 - 80
80 - 85
85 - 95
95 - 105
105 - 112
112 - 118
city
125 0 125 250 375 500
Meters
Legend
Samples
City
Channel
TSS
mg/l
24 - 30
30 - 35
35 - 40
40 - 45
45 - 50
city
125 0 125 250 375 500
Meters
Legend
Samples
City
Channel
TDS
mg/l
285 - 300
300 - 315
315 - 330
330 - 360
360 - 385
city
125 0 125 250 375 500
Meters
Legend
Samples
City
Channel
Grease & Oil
mg/l
>2.5
2.5 - 5.5
5.5 - 6
6 - 7
7 - 8
8 - 9
city
125 0 125 250 375 500
Meters
Legend
Samples
City
Channel
Phenols
mg/l
> 0.01
0.01 - 0.02
0.02 - 0.03
0.03 - 0.04
0.04 - 0.05
city
125 0 125 250 375 500
Meters
Legend
Samples
City
Channel
Chloride
mg/l
> 65
65 - 70
70 - 75
75 - 80
80 - 85
city
125 0 125 250 375 500
Meters


N
Legend
Samples
City
Channel
Flouride
mg/l
0.12 - 0.15
0.15 - 0.2
0.2 - 0.22
0.22 - 0.25
0.25 - 0.3
city
125 0 125 250 375 500
Meters
N
Legend
Samples
City
Channel
MBAs
mg/l
4.8 - 5.5
5.5 - 6.2
6.2 - 6.8
6.8 - 7.4
7.4 - 8.2
8.2 - 9.3
city
125 0 125 250 375 500
Meters
N
Legend
Samples
City
Channel
Sulphate
mg/l
85 - 102
102 - 120
120 - 140
140 - 160
160 - 180
180 - 195
city
125 0 125 250 375 500
Meters
N
Legend
Samples
City
Channel
Sulphide
mg/l
0.01 - 0.015
0.015 - 0.021
0.021 - 0.026
0.026 - 0.033
0.033 - 0.04
city
125 0 125 250 375 500
Meters
N
Legend
Samples
City
Channel
Ammonia
mg/l
0.3 - 0.6
0.6 - 1.6
1.6 - 2.6
2.6 - 3.2
3.2 - 3.7
city
125 0 125 250 375 500
Meters
N
Legend
Samples
City
Channel
Chromium
mg/l
0.01 - 0.015
0.015 - 0.025
0.025 - 0.04
0.04 - 0.058
0.058 - 0.072
0.072 - 0.08
city
125 0 125 250 375 500
Meters


N
Legend
Samples
City
Channel
Copper
mg/l
0.11 - 0.13
0.13 - 0.15
0.15 - 0.17
0.17 - 0.2
0.2 - 0.22
city
125 0 125 250 375 500
Meters
N
Legend
Samples
City
Channel
Nickel
mg/l
0.01 - 0.013
0.013 - 0.017
0.017 - 0.022
0.022 - 0.026
0.026 - 0.03
city
125 0 125 250 375 500
Meters
Legend
Samples
City
Channel
Chlorine
mg/l
0.1 - 0.18
0.18 - 0.22
0.22 - 0.27
0.27 - 0.32
0.32 - 0.36
0.36 - 0.38
0.38 - 0.4
N
city
125 0 125 250 375 500
Meters
N
Legend
Samples
City
Channel
Toxic Metals
mg/l
0.01 - 0.015
0.015 - 0.022
0.022 - 0.028
0.028 - 0.034
0.034 - 0.04
city
125 0 125 250 375 500
Meters
N
Legend
Samples
City
Channel
Zinc
mg/l
0.02 - 0.03
0.03 - 0.04
0.04 - 0.05
0.05 - 0.06
0.06 - 0.07
0.07 - 0.08
city
125 0 125 250 375 500
Meters
N
Legend
Samples
Iron
mg/l
0.54 - 0.63
0.63 - 0.70
0.70 - 0.93
0.93 - 1.17
1.17 - 1.31
City
Channel
city
125 0 125 250 375 500
Meters

Conclusion

The present study highlights that the levels of all of different pollutants were higher in urban drain compared to rural drain water. Moreover, our results regarding the concentration of different pollutants were depicted in compliance with the NEQS guideline values. Even though the pollutants were under the prescribed NEQS guideline limits but still the risks of increased contamination of water sources cannot be excluded. Thus, providing the baseline monitoring data of the understudy drains, the presented investigation would be imperatively pragmatic for water quality management and monitoring in order to improve the quality of water.

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