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Environmental crisis due to eutrophication in Ludhiana city, Punjab, India.

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Abstract

The rapid stride of industrialization, increasing population pressure and excessive use of fertilizers accelerated the problem of eutrophication in mega city of Ludhiana. The water pollution, in Buddha Nallah stream passing through the city carry sewage and industrial sludge to Sutlej River. 22 surface water samples spatially located were analyzed for quality parameters such as pH, EC, TDS, Ca^{2+}, Mg^{2+}, NO_3^{2-}, PO_4^{3-}, BOD, COD, As, Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn. The results show high level of EC, TDS, NO, BOD, COD, Chromium, Copper, Iron, Manganese and Nickel are due to the untreated effluent discharged into the water bodies and these metals become phyto-toxic at high concentrations indicating absence of self-purification mechanism in Buddha Nallah. This paper highlights the environmental crisis in the area due to eutrophication.

Keywords: Industrialization, Fertilizers, Environmental crisis and Eutrophication

INTRODUCTION

Eutrophication is a complex process which occursboth in fresh and marine water and cause excessive development of certain types of algae disturbing the aquatic ecosystems and became threat for animal and human health. The aim of the study deals with physico chemical analysis of surfacewater in both pre-monsoon (May) and post-monsoon (November) in order to determine the nutrient status of water causing eutrophication. The water of Ludhiana is polluted day by day due to industrial, agricultural as well as domestic waste and now has been on the state of eutrophication. Eutrophication is the slow aging process during which a lake, estuary, or bay evolves into a bog or marsh and eventually disappears (11). Eutrophication is the process of enrichment of nutrients in an aquatic ecosystem (18). Cultural eutrophication (excessive plant growth resulting from nutrient enrichment by human activity) is the primary problem facing most surface waters today. It is one of the most visible examples of human changes to the biosphere (5, 15). Eutrophication often results from nutrient enrichment sewage, fertilizer runoff; even decomposing leaves in street gutters can produce a human-caused increase in biological productivity called cultural eutrophication (19). Due to tremendous development of industry and agriculture, the water ecosystem has become appreciably altered in several respects in recent years and as such they are exposed to all local disturbances regardless of where they occur (17). The increasing industrialization, urbanization and developmental activities, to cope up the population explosion have brought inevitable water crisis. The health of rivers and their biological diversity are directly related to health of almost every component of the ecosystem (10). Industrial wastes and domestic sewage are the major urban sources of nutrient overload, responsible for 50% of the total amount of phosphorus unloaded into lakes from human settlements (14). Approximately 15% of the Indian population contributes phosphorus-containing wastewater effluents to rivers and lakes, resulting in eutrophication. Other sources that contribute to cultural eutrophication include the use of fertilizers, faulty septic systems, and erosion into the lake. Industrial agriculture, with its reliance on phosphate-rich fertilizers, is the primary source of excess phosphorus responsible for degrading rivers and lakes (4). The routine application of chemical fertilizers and phosphorus-laden manure has resulted in the gradual accumulation of phosphorus in soil, which washes into lakes of the watershed where it is applied. On a global basis, researchers have demonstrated a strong correlation between total phosphorus inputs and algal biomass in lakes (2). Since 1950, phosphorus inputs to the environment have been increasing as the use of phosphate-containing fertilizer, manure, and laundry detergent has become more common (8). Consequently, humans release 75% more phosphorus to the soil than would be naturally deposited by weathering of rock (3). Even increases in minute amounts of the nutrient can stimulate tremendous growth and productivity (1). According to an estimate, 400 grams of phosphates could potentially induce an algal bloom to the extent of 350 tons (13).The Green Revolution technology in the field of agriculture had put a great pressure on ecological balance, resulting in the fall of ground water table, soil resources deterioration and environmental pollution from farm chemicals. This imbalance results in global warming and ozone depletion through agricultural practices and also poisoned the environment (12) .In India many researchers have worked on physicochemical and biological characteristics of reservoir’s and rivers (6), (7), (16), and (9).

STUDY AREA

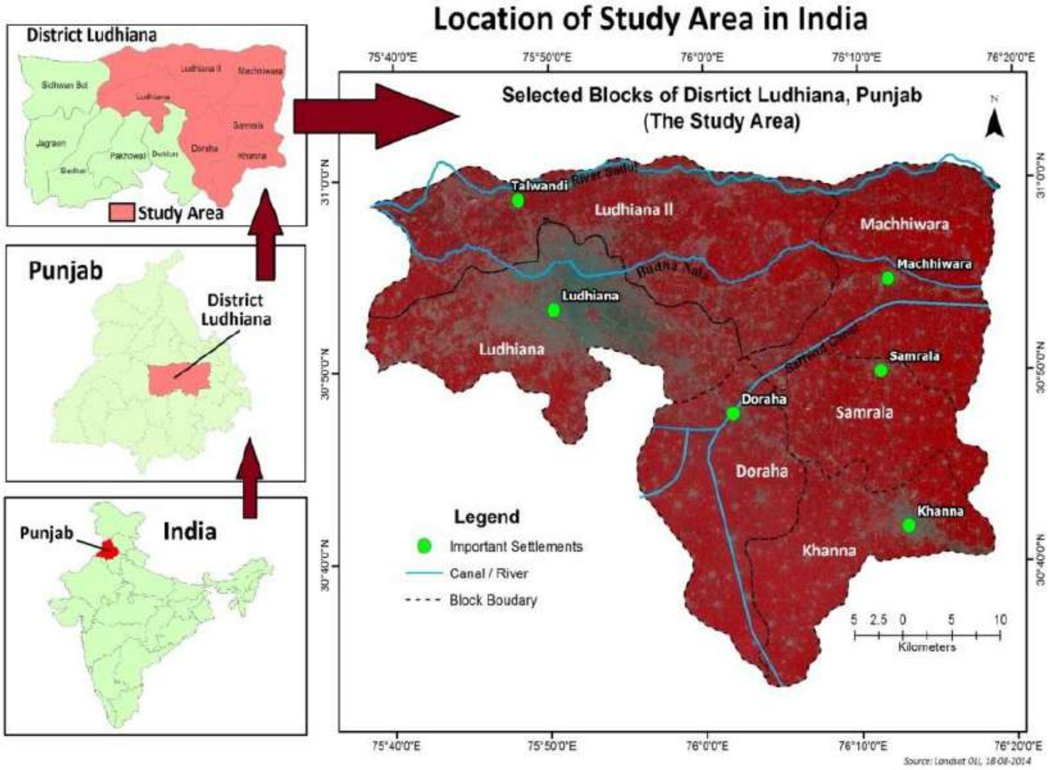


Figure 1: Location map of the study area

Geographically, Ludhiana district lies between North Latitude 30°-34' and 31°-01' and East longitude 75°-18' and 76°-20' is the most centrally located district of the State of Punjab as shown in Figure 1.Ludhiana is the first metropolitan city, popularly known as "Manchester of India." located on National Highway-I, has emerged as the most vibrant and important business center of Punjab. It is the largest city in Punjab, both in terms of area (3860 sq km) and population (approximately 34, 87,882 as per 2011 census). After the great strides in the field of agriculture, the total number of industries has increased tremendously after 1980s. The maximum exports (Rs.23.0billion) were from district Ludhiana (comprising 57.5%) of total exports from the state (Statistical Abstract, 2005) which have the severe effect on the quality of water of the Ludhiana district. There is an urgent need to reduce the anthropogenic nutrient inputs to aquatic ecosystems in order to protect the water quality and to reduce eutrophication. High nutrients intake is responsible for the proliferation of harmful algal blooms and dead zones in an aquatic ecosystem. However both these parameters have increased due to fertilizer use in agriculture, as well as from municipal and industrial water waste.

LENTIC WATER BODIES

Figure 2: Budha Nallah in Ludhiana City

The Buddha Nallah constitute thechief hydrographic feature of the areas. Budha nallah takes its rise near Chamkaur Sahib and enters Ludhiana District near village Bholapur. Buddha nallah carries the industrial and domestic waste of the Ludhiana city, indicating high level of water pollution as shown in Figure 2.

MATERIALS AND METHODS

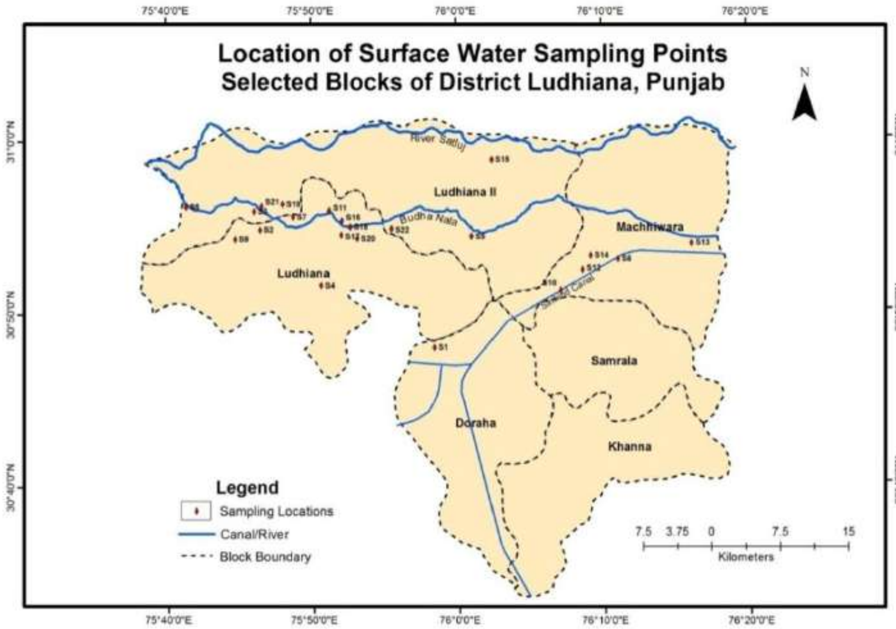


Figure 3: Surfacewater sampling points of the study area during pre and post monsoon

The hydrochemical analyses of surface water have been carried out to check the parameters causing eutrophication. 22 surface water have been collected from various water sources of Ludhiana district during the Months of May and November 2014 as shown in Figure 3. The samples from these areas have been collected from varying depths of 2.5 mtrs to 110 mtrs. Sampling, preservation and analytical protocols were conducted by standard methods. Good qualities, air tight plastic bottles with cover lock were used for sample collection and safe transfer to the laboratories for analysis. The surfacewater samples were analyzed to assess various chemical and physical water quality parameters such as (pH, EC, TDS) and major elements such as (Ca^{2+}, Mg^{2+}, NO_3^{2-},and PO_4^{3-}) were evaluated according to the standard method (APHA,2002, BIS,2012 and WHO,1996) within a short period of time to get a more reliable and accurate results. Physical parameters like EC, pH, TDS were measured on the spot at the time of sample collection using potable kit. Analysis were done for major cations (Ca^{2+} and Mg^{2+}) and anions (PO_4^{3-} and NO_3^-) using APHA method. Mean value was calculated for each parameter, with standard deviation being used as an indication of the precision of each parameter. The data were subjected to statistical analysis using different computer programmes like Minitab16, Microsoft Office Excel, Map Info. 6.5.

Parameters	Analytical Methods
Electrical Conductivity (EC)	Soil and Water analysis kit (Electronic India,model-161)
Total Dissolved Solids (TDS)	By Factor (multiplying EC with 0.65)
pH	pH meter
Calcium	Titremetry (EDTA as titrant and murexide as indicator))
Magnesium	Titremetry (EDTA as titrant and erichrome black T as indicator)
Nitrate	Spectrophotometer (Phenol disulphonic acid)
BOD	BOD Incubator (3 days at 27º C) (Winkler's Method)
COD	Dichromate reflux method

RESULTS AND DISCUSSIONS

- The pH value of surfacewater during pre-monsoon is between 6.5 to 8.5 with the mean value 7.35 and the value of surfacewater during post-monsoon varied between 5.98 to 8.3 with the average value of 7.0.
- The EC values of surfacewater during pre-monsoonranged between 326 µS/cm to 4692 µS/cm with the mean value of 1771.27 µS/cm and 315 µS/cm to 4587 µS/cm with the mean value of 1734.5 µS/cm during post-monsoon.
- The value of TDS in surfacewater varied from 211.9mg/l to 3049.8mg/l with the average value of 1151.32mg/l during pre-monsoon and 204.7mg/l to 2981.5mg/l with the average value of 1127.4mg/l during post-monsoon.
- The amount of calcium in surfacewater varied from 25.08mg/l to 76.11mg/l with the average value of 55.41mg/l during pre-monsoon and 22.31mg/l to 77.84mg/l with the average value of 53.15 during post-monsoon.
- The amount of magnesium in surfacewater during pre-monsoon varied from 6.13mg/l to35.21mg/l with the mean value of 21.91mg/l and 6.54mg/l to 34.19mg/l with the mean value of 21.30mg/l during post-monsoon.
- The concentration of nitrate in surfacewater of the study area varied between 19.14mg/l to 95.35mg/l with the mean value of 58.06mg/l during pre-monsoon and 19.13mg/l to 90.21mg/l with the mean value of 56.0mg/l during post-monsoon.
- The concentration of phosphate in surfacewater during pre-monsoon ranged between 0.021mg/l to 2.07mg/l with the mean value of 0.748mg/l and 0.021mg/l

to 2.06mg/l with the mean value of 0.69mg/l during post-monsoon.

- In pre-monsoon season the BOD concentration ranged between 51 mg/l to 192 mg/l with mean value of 119.5 mg/l in surfacewater samples.
- In post-monsoon season the concentration of BOD ranged between 49.12 mg/l to 190 mg/l with mean value of 119.4 mg/l in surfacewater samples.
- In pre-monsoon season the COD concentration of surfacewater samples ranged between 98 mg/l to 443 mg/l with mean value of 262.68 mg/l.
- In post-monsoon season the concentration of COD in the surfacewater samples ranged between 96 mg/l to 441mg/l with mean value of 262.5 mg/l.

Tables 1 and 2 show the chemical analysis of surfacewater during pre and post-monsoon followed by Table 3 which shows the surfacewater parameters above desirable and permssiblelimits.

Table 1: Chemical analysis of surfacewater sample during pre-monsoon

Parameters	**Minimum**	**Maximum**	**Average**	**Standard Deviation**
pH	6.5	8.5	7.35	0.70
EC	326	2513	1315.95	898.46
TDS	21.19	1633.45	855.37	584.00
Ca^{2+}	25.08	76.11	55.41	18.56
Mg^{2+}	6.13	35.21	21.91	9.61
NO_3^{2-}	19.14	95.35	58.06	24.59
PO_4^{3-}	0.021	2.07	0.74	0.76
COD	98	443	262.68	137.67
BOD	51	192	119.59	45.81

Table 2: Chemical analysis of surfacewater sample during post-monsoon

Parameters	Minimum	Maximum	Average	Standard Deviation
pH	5.98	8.3	7.00	6.45
EC	315	2497	1295.72	476
TDS	204.75	1623.05	842.22	309.4
Ca^{2+}	22.31	77.84	53.15	33.78
Mg^{2+}	6.54	34.19	21.30	10.13
NO_3^{2-}	19.13	90.21	56.00	28.03
PO_4^{3-}	0.021	2.06	0.09	0.08
COD	96	441	262.5	127
BOD	49.12	190	119.41	64

Table 3: Surfacewater parameters above desirable and permissible limits

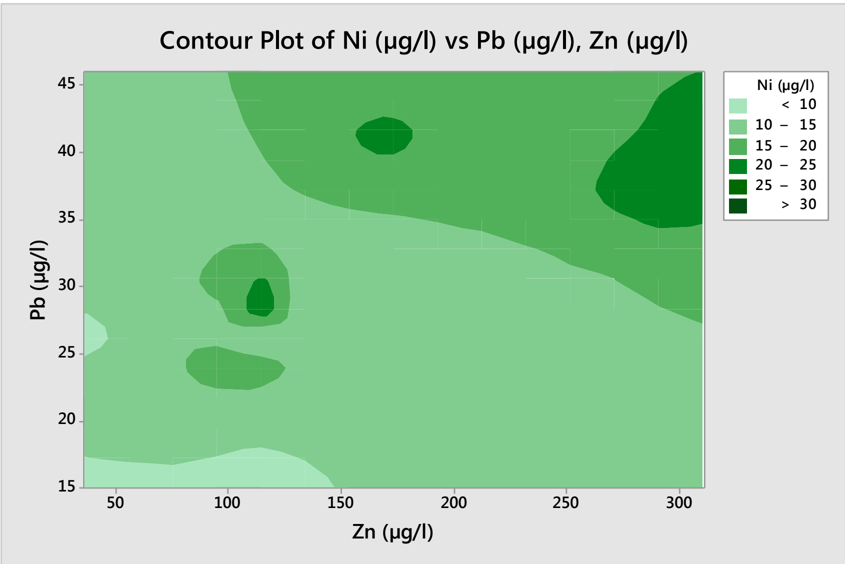
Parameters	Maximum permissible limit for drinking water	Maximum desirable limit for drinking water	No. of surface water samples analyzed	No. of samples above permissible limit / %	No. of samples above desirable limit / %
EC	0-2000µS/cm	750µS/cm	22	10 / (45.45)%	Nil
TDS	2000mg/l	500mg/l	22	Nil	10 / (45.45)%
pH	No Relaxation	6.5 -8.5	22	Nil	Nil
Ca^{2+}	200mg/l	75mg/l	22	Nil	02/ (9.09)%
Mg^{2+}	100 mg/l	30 mg/l	22	Nil	06 / (27.27)%
NO_3^{2-}	No relaxation	45mg/l	22	Nil	16 / (72.72)%
COD	No guidelines	---------	22	-------	-------
BOD	2mg/l	----------	22	16/ (72.72) %)	--------

STATUS OF HEAVY METALS IN SURFACEWATER

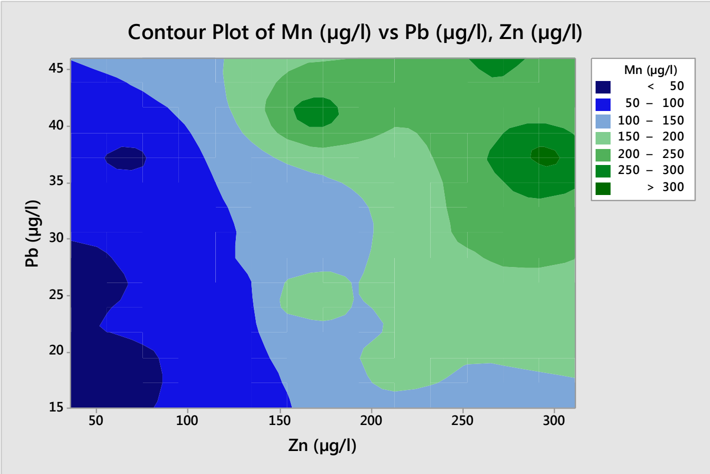
- The cadmium content in the surfacewater ranged between 2µg/l to 5µg/l with the average value of 3.04 µg/l.
- The concentration of iron in the surfacewater of the Ludhiana district ranged between 76 µg/l to 582 µg/l with the average value of 266.09 µg/l.
- The concentration of arsenic in the surfacewater of the study area ranged between11 µg/l to 39 µg/l with the average value of 24.40 µg/l.

- Lead concentration in the surfacewater of the study area ranged between 15 µg/l to 46 µg/l with the average value of 28.36 µg/l.
- The concentration of chromium in the surfacewater of the study area ranged between 9 µg/l to 51 µg/l with the average value of 26.86 µg/l.
- The concentration of copper in the surfacewater of the study area ranged between 47 µg/l to 532 µg/l with the average value of 155.5 µg/l.
- The concentration of manganese in the surfacewater of the study area ranged between 11 µg/l to 309 µg/l with the average value of 120.54 µg/l.
- The nickel concentration in the surfacewater of the study area ranged between 6 µg/l to 31 µg/l with the average value of 13.81 µg/l.
- The zinc concentration in the surfacewater of the study area varies from 36 µg/l to 311 µg/l with the average value of 141.81 µg/l.

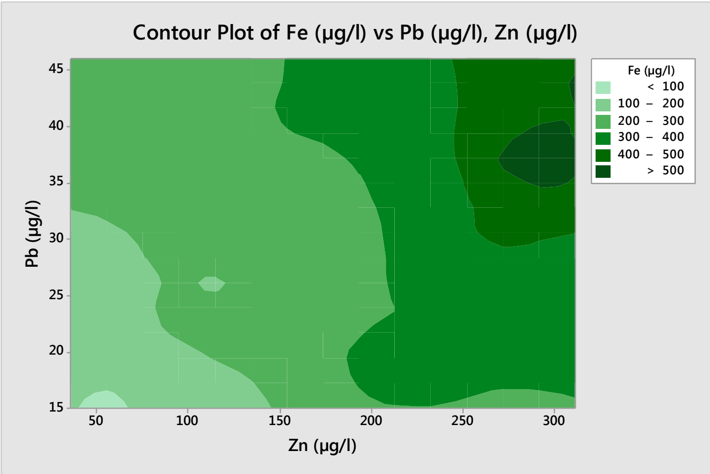
The status of heavy metal in surfacewater of the study area are shown in the form of contours in Figure 4 (a-g) followed by Table 4 showing parameters of heavy metals in surfacewater above permissible and desirable limit



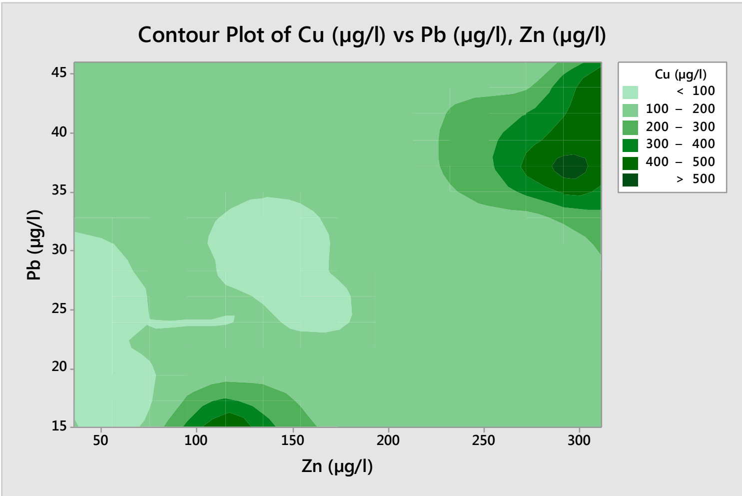
(a)


Contour Plot of Mn (µg/l) vs Pb (µg/l), Zn (µg/l)
Mn (µg/l)
< 50
50 – 100
100 – 150
150 – 200
200 – 250
250 – 300
> 300
Pb (µg/l)
Zn (µg/l)
15
20
25
30
35
40
45
50
100
150
200
250
300

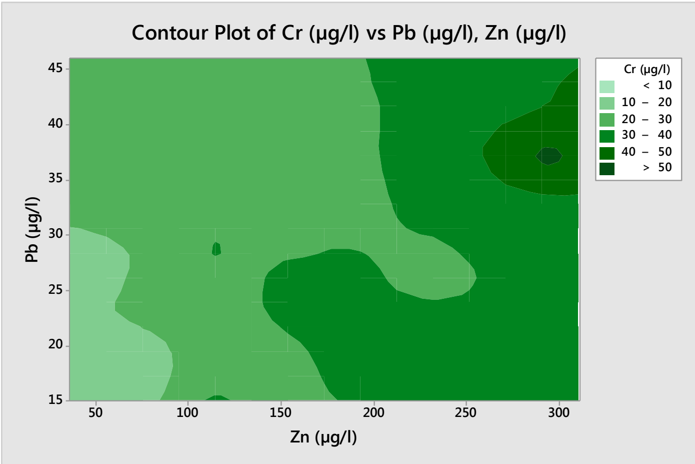
(b)


Contour Plot of Fe (µg/l) vs Pb (µg/l), Zn (µg/l)
Fe (µg/l)
< 100
100 – 200
200 – 300
300 – 400
400 – 500
> 500
Pb (µg/l)
Zn (µg/l)
15
20
25
30
35
40
45
50
100
150
200
250
300

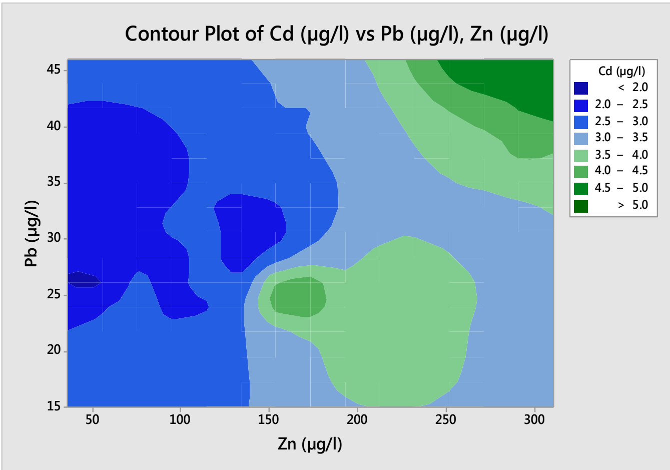
(c)


Contour Plot of Cu (µg/l) vs Pb (µg/l), Zn (µg/l)
Cu (µg/l)
< 100
100 – 200
200 – 300
300 – 400
400 – 500
> 500
Pb (µg/l)
Zn (µg/l)
15
20
25
30
35
40
45
50
100
150
200
250
300

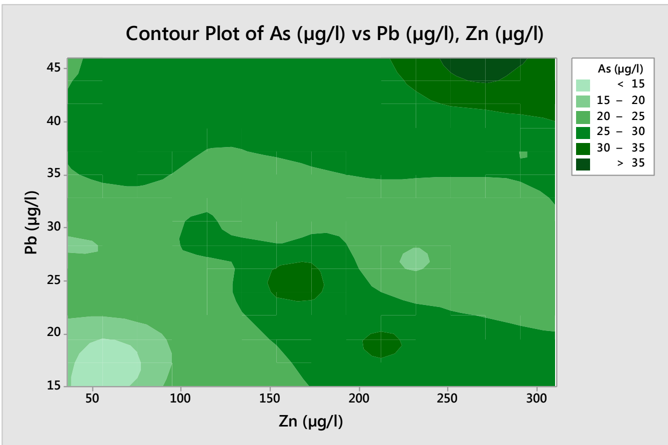
(d)


Contour Plot of Cr (µg/l) vs Pb (µg/l), Zn (µg/l)
Pb (µg/l)
45
40
35
30
25
20
15
50
100
150
200
250
300
Zn (µg/l)
Cr (µg/l)
< 10
10 – 20
20 – 30
30 – 40
40 – 50
> 50

(e)


Contour Plot of Cd (µg/l) vs Pb (µg/l), Zn (µg/l)
Pb (µg/l)
45
40
35
30
25
20
15
50
100
150
200
250
300
Zn (µg/l)
Cd (µg/l)
< 2.0
2.0 – 2.5
2.5 – 3.0
3.0 – 3.5
3.5 – 4.0
4.0 – 4.5
4.5 – 5.0
> 5.0

(f)


Contour Plot of As (µg/l) vs Pb (µg/l), Zn (µg/l)
Pb (µg/l)
45
40
35
30
25
20
15
50
100
150
200
250
300
Zn (µg/l)
As (µg/l)
< 15
15 – 20
20 – 25
25 – 30
30 – 35
> 35

(g)

Table 4: Parameters of heavy metals in surfacewater above permissible and desirable limit

Parameters	Units	Maximum	Minimum	Mean	Standard deviation	Permissible limit (PL)	Desirable Limit (DL)	%PL	%DL
pH		8.5	6.5	7.35	0.7	6.5-8.5	NIL	NIL	NIL
EC	µS/cm	2513	326	1316	898	2000	750	45.4%	NIL
TDS	mg/l	1633.45	211.9	855.37	584	2000	500	NIL	45.4%
As	µg/l	39	11	24	7	50	NIL	NIL	NIL
Cd	µg/l	5	2	3.05	1.05	10	NIL	NIL	NIL
Cr	µg/l	51	9	27	11	50	NIL	4.5%	NIL
Cu	µg/l	532	47	156	154	1500	500	NIL	13.6%
Fe	µg/l	582	76	266	137	1000	300	NIL	45.4%
Mn	µg/l	309	11	121	94.5	300	100	4.5%	45.4%
Ni	µg/l	31	6	13.8	6.82	20	NIL	22.7%	NIL
Pb	µg/l	46	15	28.4	8.33	50	NIL	NIL	NIL
Zn	µg/l	311	36	142	86.4	15000	5000	NIL	NIL

CONCLUSION

The high pH of the water may be due to the presence of carbonates and bicarbonates. High concentration of nitrates is due to fertilizers used in agriculture. The COD and BOD values of the study area are above the permissible limits which indicate the presence of high organic pollution loading. This is mainly due to the high population density and presence of industries in the area. High level of chromium, copper, iron, manganese and nickel are due to the untreated effluent discharged into the water bodies and these metals become phyto-toxic at high concentrations.

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