Assessment of various heavy metals in surface water of polluted site in middle stretch of river Ganga, Kanpur, UP: a study for ecological impact

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The aim of the present study is to identify different types of domestic wastes, leather tanning industries effluents etc. being discharged into the river Ganga, complete physico chemical analysis of river water and sewage into the water bodies leading to the entropic condition in the river water. Special emphasis has been given on specific role of variety of pollutants, heavy metals coming through domestic wastes and industrial effluents on the chemistry of Ganga river water.

Keywords: Pesticides, Pharmaceuticals, Turbidity, Microbial Pollution, Heavy metals,

Introduction

The Ganga rises in the Garhwal Himalaya (30^{0}55'N, 79^{0}7'E) under the name of Bhagirathi. The ice-cave of Gaumukh at the snout of the Gangotri glacier, some 4100 meters above sea level, is recognized as the traditional source of the Ganga. The Ganga has by far the largest river basin in India, draining as much as 861404 km^2 with, covering more than a quarter (26.2%) of India's total geographical areas. Having a large surface water and ground water resources with an annual flow of 468.7 billion cubic meters (25.2% of India's total water resources), it is all the more important that the level of pollution is kept at the minimum possible with in the Gangetic basin. The Ganga water is widely used for domestic and industrial purposes in towns and villages located on its course for which it is also equally necessary to continuously watch the level of possible pollution of the water in different seasons so that adequate measures can be taken to keep the concentration of various pollutants in the water within permissible limits of toxicity. Pollution from industrial and urban wastes has no doubt, serious deleterious effects in the water quality in the Gangetic basin, but at the same time the water runoff from rural settlements, cattle pans, agriculture farms, etc. in the river is likely to be toxic enough to pollute the prevailing water bodies and drainage systems, the heavy silt load causes navigational problems and other environmental hazardous in the Ganga river.

The problem of pollution of the Ganga water due to discharge of industrial effluents, sewage and domestic waste agricultural discharge, fertilizers, detergents, toxic and heavy metals, siltation, thermal pollutants, and radioactive materials is getting more and more serious. The domestic sewage contains trace quantities of toxic metals such as Cu, Cr, Zn, Mn, Pb and Ni sewage contains decomposable organic matter which exert an influence on oxygen demand when flows into water. Organic matter generally includes fatty acids esters, amino acids, amides, and amines etc. Industrial effluents discharge contains toxic chemical hazardous compounds, phenols, aldehydes, ketones, amines, cyanides, metallic wastes, plasticizers, toxic acids, corrosive alkalies, oils, greases, dyes, bio acids, suspended solids, non-biodegradable matter, radioactive wastes and thermal pollutants. Plant's nutrients, pesticides, insecticides, herbicides, fertilizers, farm wastes, manure slurry, sediments, drainage from silage, plants and animals debris, containing mostly the inorganic material are reported to cause heavy pollution to water resources. Traces of heavy metals such as Hg, Cd, Pb, As, Co, Mn, Fe, and Cr have been identified as dexterous to aquatic ecosystem and human health.

There was a need for a detailed description of the sampling and preservation procedures for accurate analysis of the samples as the results of various physical and chemical analysis of the samples would be used to predict the quality of river Ganga water.

The samples were the fractional representatives of the whole system both in physical and chemical information about the quality of the water of river Ganga.

The composite soil samples for sediment and analysis were collected during each season from 15-20 cm depth of surface layer at a distance of approx 55m away from sampling points of river water. The samples from all the six sites were collected from the middle stream of the river that too 1 ft and 2 ft deep water from the top surface of the river. Water samples collected from different heights were mixed in equal volumes and preserved in 500 ml glass bottles. The same procedure was followed for collection of water sample form all sites (Kanpur City) in all seasons.

1. Sample station I (site I) – Bithoor Ghat
2. Sample station II (site II) –Bhairav Ghat
3. Sample station III (site III) - Sarsaaiya Ghat
4. Sample station IV(site IV) – Gola Ghat
5. Sample station V (site V) – Sidha Nath Ghat
6. Sample station VI (site VI) – Devri Ghat

Causes of Pollution:

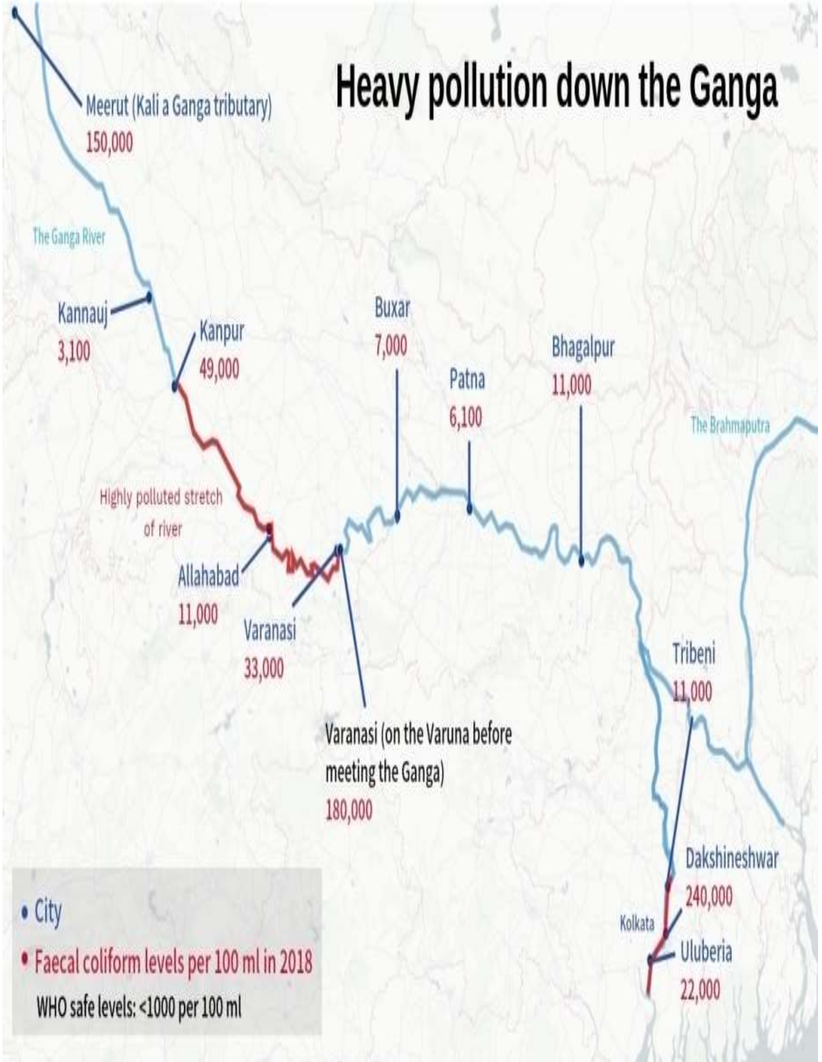
A number of materials constitute solid wastes which are either domestic or industrial. The solid wastes include the following pollution:

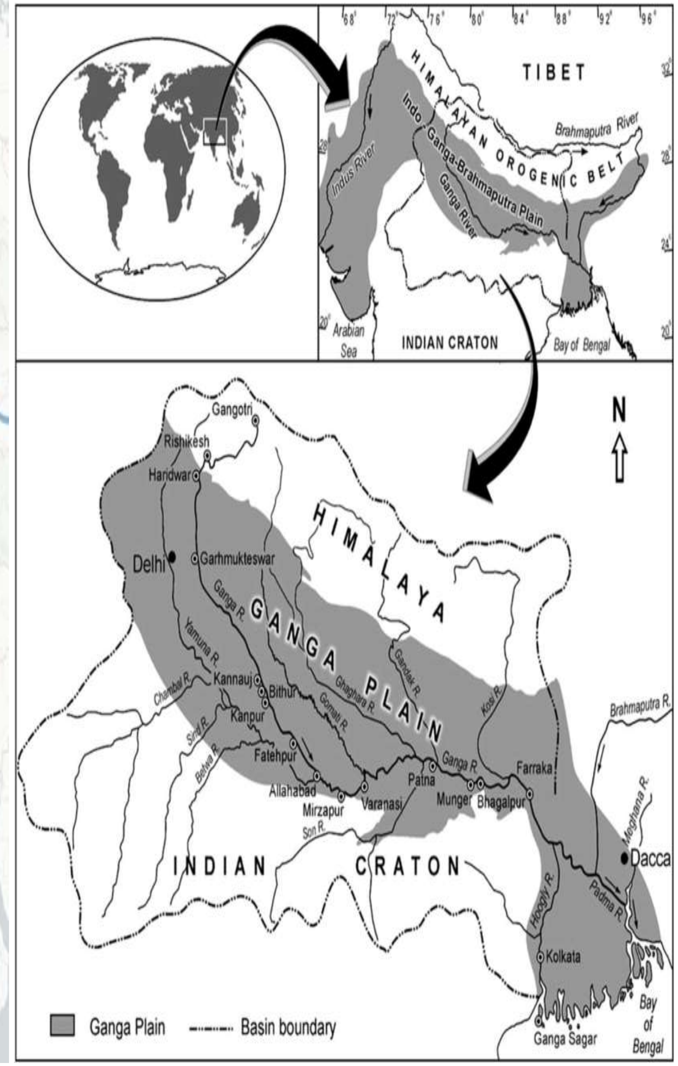
(i) Garbage, such as wastes from kitchen, slaughter houses & freezing industries.
(ii) Rubbish combustible wastes, such as leaves, grasses, plants from the garden and non-combustible wastes such as bottles, crockery and plastic materials.
(iii) Ashes
(iv) Large wastes formed due to demolition
(v) Dead animal wastes
(vi) Sludge, settled solid components of sewage wastes
(vii) Industrial solid wastes for example, chemicals, paints, sand etc.
(viii) Mining wastes, such as wastes from coal mine.
(ix) Agricultural wastes, such as farm animal wastes, manure, crop residues, pesticides, insecticides and so on.

Pollution caused by liquid wastes is mainly organic waste. The most important source of organic wastes is sewage which contains faecal matter, urine, kitchen and soil washings. It contains large number of bacteria both pathogenic and non-pathogenic. Domestic sewage in small quantities rarely gives trouble. However, liquid industrial wastes along with acid or alkali and poisonous substances like cyanide etc. affects the aquatic life and results into impairing of self-purification system of water body. Surface run off from agriculture field can carry nitrogen and phosphorous fertilizer that increase the aquatic plant life and later undergo decomposition adding to the organic stress of the streams. Pesticides and herbicides which enter waters body may kill aquatic life or to give rise cumulative poisoning. The gaseous wastes are most dangerous to animals and plants. CO, SO, NO_2, O_3 and so called "smog gases" made up of complex mixtures of hydrocarbon are common gaseous pollutants. CO is a product of incomplete combustion and deadly poisonous at high concentration. Of the common gaseous pollutants, SO_2 is regarded as one of the most dangerous gaseous to human health as it attacks the respiratory tracts and interferes in breathing mechanism.

Results and Discussion

The solids which are not dissolved in water and may be removed by filtration are the suspended solids. Organic matter and living microorganisms are also included in suspended solids (Dara,2000).Total suspended solids (T.S.S.) is equal to the difference of total solid (T.S). and total dissolved solid (T.D.S.). T.S.S. value was found to vary from 77.00 to 118.00 mgL^{-1} in winter season, 77.10 to 125.00 mgL^{-1} in summer season and 82.00 to 144.00 mgL^{-1} in in rainy season (ref, table 1). The location of research site (Kanpur) is shown in figure and the pollution status of river ganga is also represented in given map.

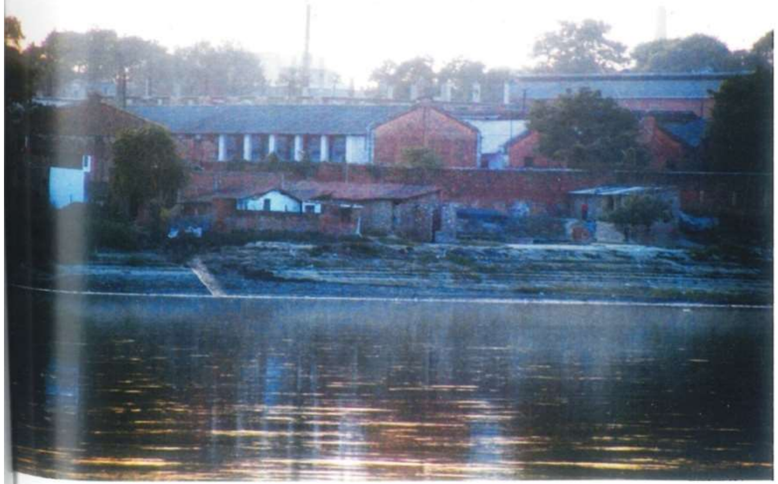




Location of Bhairav Ghat on the Bank of Ganga River

Burhiya Nala - Near Sidhnath Ghat (Jajmau Bridge)

Power House Nala (main) - Near Parmath (Behind Elgin Mill)



Bengali Nala - Near Jajmau Bridge (Near Railway Bridge)

Table 1

MEAN VALUES OF PHYSICAL, CHEMICAL AND BIOLOGICAL PARAMETERS OF RIVER GANGA AT KANPUR SHOWING SEASONAL VARIATIONS

W-winter (Nov.-Feb) S-summer (March-June) R-rain (July.-Oct)

Sampling station	Colour			Temperature(^{0}C)			pH			T.S.S.(mgL-1)			T.D.S.(mgL-1)		
	W	S	R	W	S	R	W	S	R	W	S	R	W	S	R
station I	colourless	colourless	colourless	13.0	33.0	30.1	7.04	7.04	7.30	77.00	77.10	82.00	278.00	299.00	302.00
SD				±3.8	±2.5	±2.1	±0.25	±0.25	±0.43	±2.0	±1.001	±2.646	±4.0	±3.464	3.464
station II	colourless	colourless	colourless	13.0	32.8	30.0	7.04	7.04	7.40	78.00	78.00	83.00	280.00	300.00	308.00
SD				±3.5	±2.5	±3.0	±0.25	±0.25	±0.32	±3.0	±4.359	±3.0	±10.0	±5.0	4.0
station III	Yellow	Brown	colourless	13.0	32.8	30.0	6.52	6.60	6.80	84.00	92.00	102.00	302.00	315.00	340.00
SD				±3.5	±2.5	±2.6	±0.33	±0.31	±0.25	±3.0	±2.0	±3.464	±2.0	±4.0	4.359
station IV	Yellow	Brown	colourless	15.5	35.4	29.5	7.62	7.52	7.70	102.00	111.00	132.00	363.0	375.0	404.0
SD				±2.8	±2.6	±2.1	±0.33	±0.21	±0.31	±2.0	±3.606	±8.0	±3.0	±7.0	6.928
station V	Yellow	Brown	colourless	15.3	35.0	30.1	8.0	8.20	8.35	118.0	125.0	144.0	428.0	440.0	464.0
SD				±2.4	±2.4	±2.4	±0.08	±0.25	±0.19	±12.49	±5.0	±4.0	±20.0	±17.321	14.0
station VI	Brown	Brown	colourless	16.2	35.1	31.20	7.20	7.35	7.10	85.0	99.0	120.0	330.0	343.0	370.0
SD				±2.9	±3.0	±2.8	±0.08	±0.06	±0.33	±5.0	±3.0	±3.0	±17.321	7.211	10.0

Mean=±S.D. SD.= Standard Deviation, T.S.S. = Total Suspended Solids & T.D.S. = Total Dissolved Solid

Table 2

MEAN VALUES OF PHYSICAL, CHEMICAL AND BIOLOGICAL PARAMETERS OF RIVER GANGA AT KANPUR SHOWING SEASONAL VARIATIONS

W-winter (Nov.-Feb) S-summer (March-June) R-rain (July.-Oct)

Mean=±S.D.

Sampling Station	Turbidity(N.T.U)			Dissolved silica (mgL^{-1})			Free CO_2(mgL^{-1})		
	W	S	R	W	S	R	W	S	R
station I	9.15	10.16	12.13	2.45	2.30	3.50	3.38	2.54	2.75
SD	±0.132	±0.173	±1.0	±0.05	±0.10	±0.173	±0.04	±0.04	±0.05
station II	10.20	12.10	13.80	2.50	2.50	4.30	3.50	2.96	3.60
SD	±0.2	±1.0	±0.917	±0.2	±0.1	±0.173	±0.5	±0.087	±0.3
station III	35.00	38.00	41.00	5.40	4.30	5.50	4.80	3.80	5.06
SD	±2.0	±3.464	±1.732	±0.4	±0.3	±0.5	±0.4	±0.436	±0.06
station IV	52.10	55.15	66.20	6.20	5.80	6.80	5.80	4.64	5.80
SD	±52.10	±55.15	±66.20	±6.20	±5.80	±6.80	±5.80	±4.64	±5.80
station V	73.15	75.20	84.00	7.30	7.00	8.12	6.58	5.30	7.30
SD	±5.132	±5.0	±4.0	±0.3	±0.361	±0.156	±0.5	±0.3	±0.141
station VI	44.00	46.00	57.00	5.60	4.80	5.70	5.20	3.84	5.84
SD	±3.0	±2.0	±4.0	±0.6	±0.529	±0.7	±0.346	±0.069	±0.16

S.D = Standard Deviation N.T.U. = Nephometric turbidity unit

Table 3

MEAN VALUES OF PHYSICAL, CHEMICAL AND BIOLOGICAL PARAMETERS

OF RIVER GANGA AT KANPUR SHOWING SEASONAL VARIATIONS

W-winter (Nov.-Feb) S-summer (March-June) R-rain (July.-Oct)
Mean=±S.D.

Sampling station	Conductivity(μmhocm-1)			Total hardness(mgL^{-1})			D.O(mgL^{-1})			B.O.D(mgL^{-1})			C.O.D.(mgL^{-1})		
	W	S	R	W	S	R	W	S	R	W	S	R	W	S	R
Station I	160.00	170.0	140.0	173.0	184.0	170.0	9.40	8.40	9.20	2.46	2.57	2.37	8.64	8.98	7.90
SD	±5.0	±10.0	±4.359	±5.196	±4.0	±5.0	±0.4	±0.693	±0.346	±0.087	±0.1	±0.3	±0.069	±0.191	±0.265
Station II	162.00	172.0	142.0	184.0	188.0	180.0	9.40	8.40	9.20	2.56	2.80	2.43	8.80	9.24	8.20
SD	±3.464	±8.00	±4.0	±3.464	±5.0	±2.0	±2.0	±0.173	±0.2	±0.118	±0.529	±0.052	±0.2	±0.329	±0.173
Station III	399.99	400.02	199.98	189.0	199.0	182.0	9.30	8.00	9.00	6.20	6.80	5.20	16.0	16.98	12.40
SD	±20.0	±13.23	±95.39	±10.0	±19.0	±6.083	±0.3	±0.2	±0.08	±0.173	±0.6	±0.361	±0.436	±0.8	±0.4
Station IV	480.00	510.0	210.0	205.0	209.0	204.0	8.00	6.50	7.80	8.40	9.50	7.50	24.0	24.80	16.40
SD	±30.0	±26.458	±10.0	±5.0	±9.0	±4.0	±0.2	±0.5	±0.346	±0.3	±0.5	±0.624	±20.	±3.0	±0.954
Station V	790.0	800.00	390.0	208.0	220.0	206.0	7.20	5.40	6.80	9.00	10.80	8.60	32.90	36.80	26.80
SD	±17.321	±51.962	±30.0	±8.0	±20.0	±6.0	±0.2	±0.4	±0.265	±0.1	±0.436	±0.265	±2.0	±2.646	±2.646
Station VI	420.00	450.00	210.0	199.0	207.0	184.0	8.90	7.60	8.6	6.40	7.20	5.90	18.20	20.20	13.50
SD	±15.0	±8.66	±9.165	±9.0	±7.0	±4.0	±0.2	±0.3	±0.6	±0.3	±0.173	±0.265	±2.107	±0.917	±0.866

S.D.= Standard Deviation, D.O.= Dissolved Oxygen, C.O.D.=Chemical Oxygen Demand
B.O.D =Biological Oxygen Demand.

Table 4

MEAN VALUES OF PHYSICAL, CHEMICAL AND BIOLOGICAL PARAMETERS OF RIVER GANGA AT KANPUR SHOWING SEASONAL VARIATIONS

W-winter (Nov.-Feb) S-summer (March-June) R-rain (July.-Oct)

Mean=±S.D.

Sampling station	Alkalinity (mgL-1)			Sulphate (mgL^{-1})			phosphate(mgL^{-1})			Chloride (mgL^{-1})			Calcium (mgL^{-1})		
	W	S	R	W	S	R	W	S	R	W	S	R	W	S	R
Station I	130.0	120.0	106.0	26.60	24.80	22.0	0.68	0.87	0.60	21.10	22.20	20.0	22.40	26.40	18.70
SD	±5.0	±3.0	±2.646	±0.872	±4.0	±2.0	±0.02	±0.02	±0.017	±1.054	±1.908	±1.323	±0.40	1.249	0.608
Station II	136.0	124.0	110.0	27.00	25.00	22.80	0.72	0.89	0.66	22.60	23.00	21.0	22.40	27.70	20.20
SD	±5.196	±2.646	±1.732	±2.0	±0.866	±0.8	±0.01	±0.02	±0.015	±1.039	±5.0	±1.323	±1.833	1.7	1.114
Station III	180.0	156.10	142.0	34.40	32.12	28.28	1.54	1.72	1.22	38.20	41.0	30.80	32.24	36.26	28.46
SD	±7.0	±6.0	±3.464	±2.0	±3.466	±3.0	±0.046	±0.035	±0.017	±0.916	±1.732	±1.179	1.908	2.873	1.4
Station IV	208.0	170.0	162.0	38.80	32.40	28.42	2.28	2.74	1.82	45.20	48.20	35.0	56.34	61.43	50.50
SD	±7.55	±5.0	±2.0	±3.0	±0.917	±0.872	±0.08	±0.04	±0.035	±0.2	±0.916	±1.5	2.839	2.623	2.784
Station V	256.0	236.0	212.0	46.20	43.30	40.0	3.70	4.0	3.00	50.80	56.80	38.80	62.0	68.80	53.0
SD	±6.0	±11.015	±3.464	±2.905	±2.166	±2.466	±0.7	±0.2	0.173	±3.666	±1.833	±2.663	1.732	2.905	3.606
Station VI	201.0	172.00	152.0	35.50	31.80	27.88	1.86	2.0	1.54	38.42	42.20	31.80	36.60	38.80	30.70
SD	±2.646	±6.245	±3.464	±0.866	±0.8	±1.96	±0.2	±0.173	±0.021	±0.6	±2.905	±0.872	0.889	0.529	1.8

S.D. = Standard Deviation

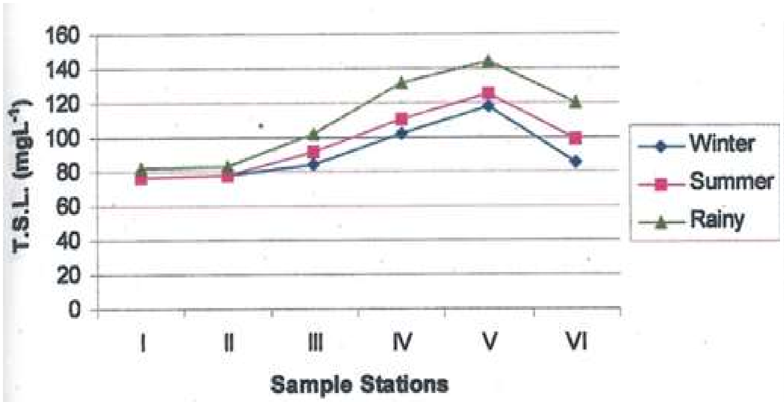
Table 5

MEAN VALUES OF PHYSICAL, CHEMICAL AND BIOLOGICAL PARAMETERS OF RIVER GANGA AT KANPUR SHOWING SEASONAL VARIATIONS

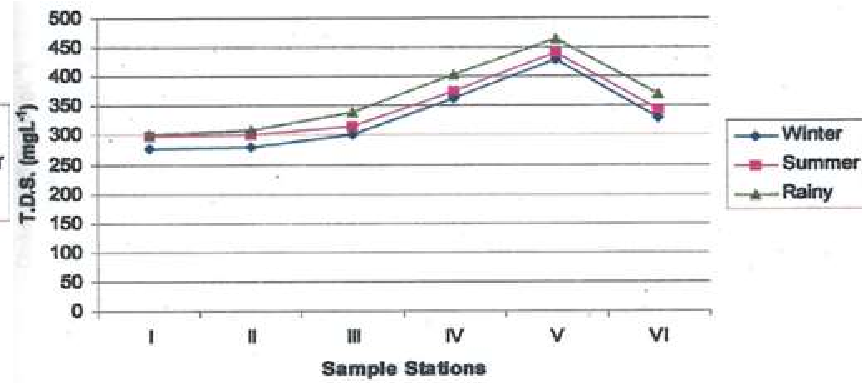
W-winter (Nov.-Feb) S-summer (March-June) R-rain (July.-Oct)

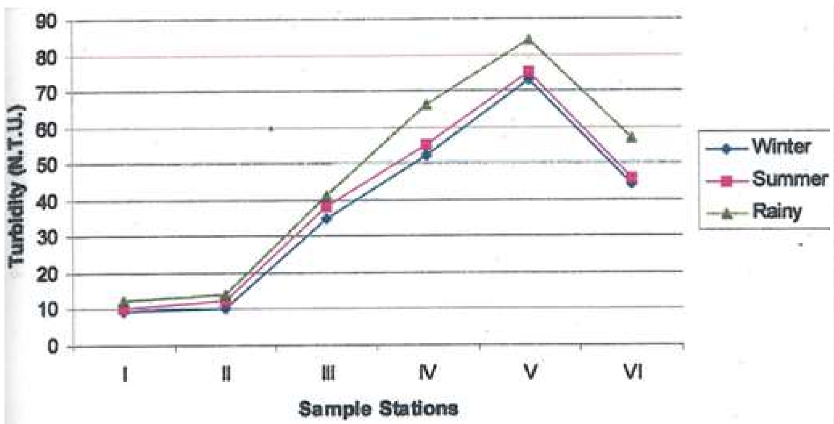
Mean=±S.D.

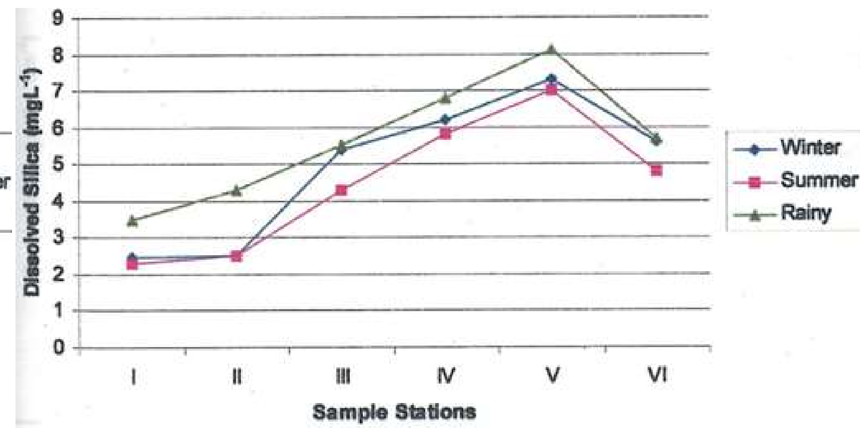
Sampling station	Iron (mgL^{-1})			cadmium(mgL^{-1})			Copper (mgL^{-1})			Lead (mgL^{-1})			Manganese (mgL^{-1})		
	W	S	R	W	S	R	W	S	R	W	S	R	W	S	R
Station I	0.538	0.560	0.470	ND	ND	ND	0.023	0.025	0.020	0.031	0.035	0.030	0.042	0.044	0.040
SD	±0.02	±0.03	±0.07				±0.04	±0.00	±0.01	±0.000	±0.01	±0.00	±0.00	±0.00	±0.00
Station II	0.569	0.582	0.501	ND	ND	ND	0.023	0.025	0.020	0.032	0.035	0.032	0.042	0.044	0.041
SD	±0.26	±0.25	±0.25				±0.04	±0.00	±0.01	±0.00	±0.00	±0.00	±0.00	±0.00	±0.00
Station III	0.742	0.737	0.542	T	T	ND	0.032	0.040	0.031	0.050	0.055	0.042	0.080	0.100	0.075
SD	±0.02	±0.23	±0.029				±0.03	±0.01	±0.01	±0.00	±0.00	±0.00	±0.00	±0.00	±0.00
Station IV	1.421	1.432	1.019	T	T	T	1.100	1.120	0.095	0.062	0.067	0.054	0.112	0.140	0.085
SD	±0.03	±0.23	±0.25				±0.04	±0.12	±0.03	±0.00	±0.00	±0.01	±0.00	±0.00	±0.00
Station V	2.150	2.321	1.878	T	T	T	1.120	1.180	1.100	0.068	0.072	0.061	0.152	0.184	0.116
SD	±0.35	±0.07	±0.05				±0.02	±0.01	±0.01	±0.00	±0.01	±0.00	±0.00	±0.00	±0.00
Station VI	0.792	0.810	0.602	ND	ND	ND	0.092	0.099	0.086	0.058	0.061	0.051	0.085	0.112	0.080
SD	±0.25	±0.26	±0.22				±0.21	±0.12	±0.07	±0.00	±0.00	±0.00	±0.00	±0.00	±0.00


T.S.L. (mgL-1)
160
140
120
100
80
60
40
20
0
I
II
III
IV
V
VI
Sample Stations
Winter
Summer
Rainy

1


T.D.S. (mgL-1)
500
450
400
350
300
250
200
150
100
50
0
I
II
III
IV
V
VI
Sample Stations
Winter
Summer
Rainy


Turbidity (N.T.U.)
90
80
70
60
50
40
30
20
10
0
I
II
III
IV
V
VI
Sample Stations
Winter
Summer
Rainy


Dissolved Silica (mgL-1)
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8
7
6
5
4
3
2
1
0
I
II
III
IV
V
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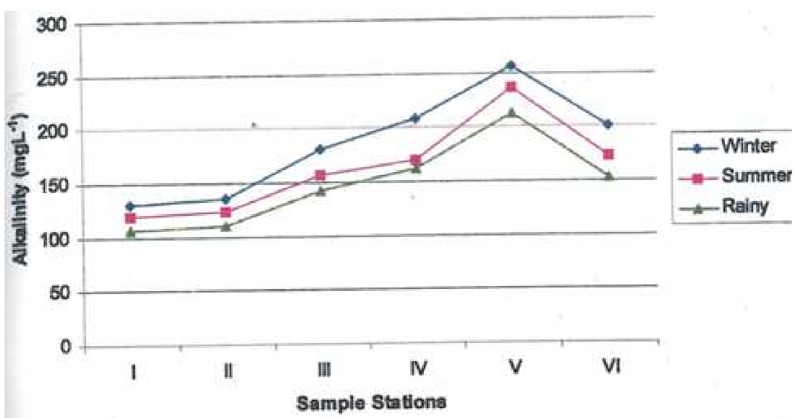
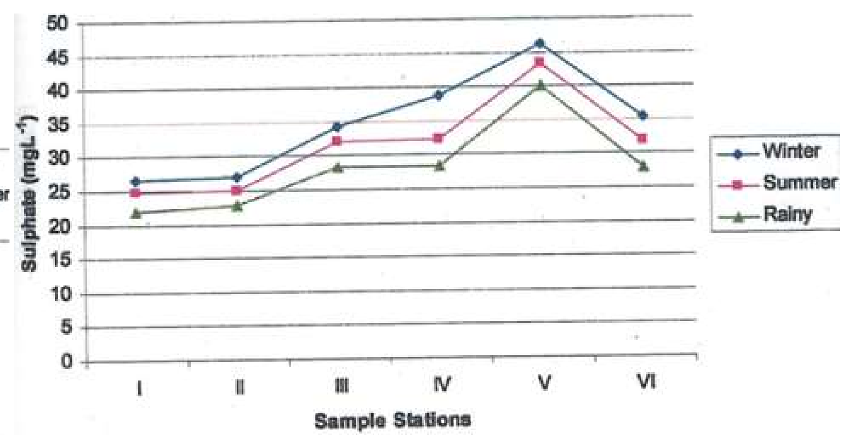
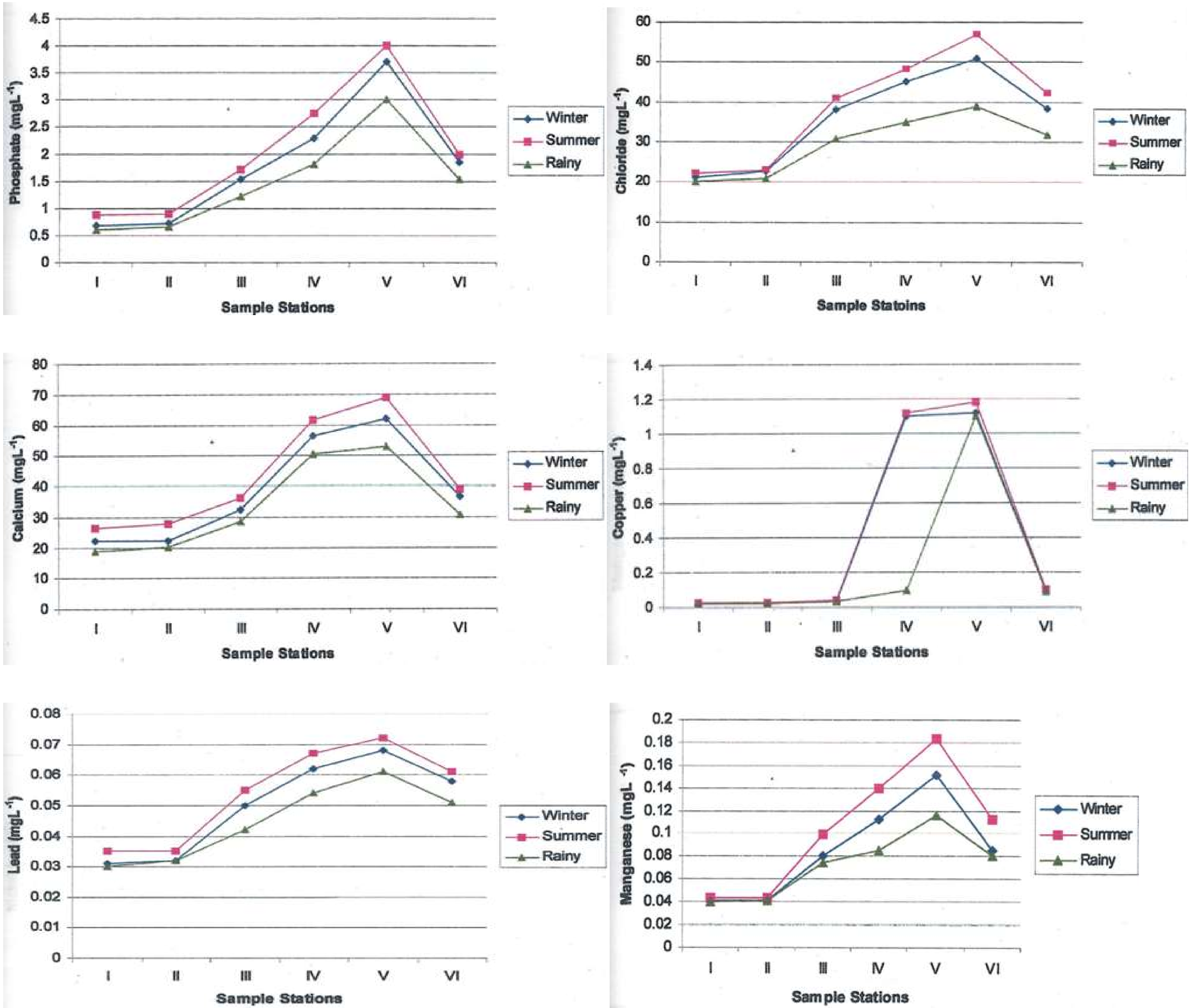
Sample Stations
Winter
Summer
Rainy


Alkalinity (mgL-1)
300
250
200
150
100
50
0
I
II
III
IV
V
VI
Sample Stations
Winter
Summer
Rainy


Sulphate (mgL-1)
50
45
40
35
30
25
20
15
10
5
0
I
II
III
IV
V
VI
Sample Stations
Winter
Summer
Rainy


Phosphate (mgL-1)
Chloride (mgL-1)
Calcium (mgL-1)
Copper (mgL-1)
Lead (mgL-1)
Manganese (mgL -1)
Winter
Summer
Rainy
I
II
III
IV
V
VI
Sample Stations
Sample Statoins

The result (table.1) clearly shows that the maximum suspended values at all station had been found during rainy season which decreased to become minimum during winter season. The higher values of suspended solids at station IV and at station V may be attributed due to regular discharge of the waste of city ,hospital and effluent of factories of the area is dumped through power house nala and O.E.F nala before station IV and the waste of leather industries and other small industries pour its polluted waste into Ganga river through Bengali nala and Burhiya nala before station V containing high amounts of suspended matter which spurt the suspended contents in river Ganga. The observations regarding the variation in mean suspended solids values coincide with the studies made by several workers Shah (1983), Sunder (1988) for river Jhelum and Kashmir region, Pandey et al.,(1989) for NamaKosi of Kumaun region. The higher TDS values at station V may be due to merger of the effluent discharge from leather industries and Bengali and Burhiya nala of the city which joins the river before station V, it may be accounted due to the presence of the dissolved phosphates, sulphates and chlorides of calcium, potassium, iron etc. Grigg (1972), Thomos (1986) and Trivedi (1988) have reported the same observation under the similar conditions.
The observed values of turbidity varied from 9.15 to 73.15 NTU in winter season 10.16 to 75.20 in summer season, and 12.13 to 84.00 NTU in rainy season. The deleterious effect of high turbidity values have also been discussed by Pal et. al. (1960); Unni (1971); Bolen et al (1975); Kaul et. al. (1978); Shina and Sahai (1973); Shah and Abbas (1979) and Kunil and Maeda, (1982). Their observations support our observations.

The value of dissolved silica was quite low, ranged from 2.3 to 8.12 mgL-1. Increase in silica is associated with the presence of diatoms, hence there is aco-relation of silica diatoms, Hutchimson (1975) has stated that the diatoms consume silica and bring considerable variations in its concentrations.

During rainy season the main source of silica are land run off and precipitation. Concentration of silica did not show marked variation during seasonal changes. Reduction in the value of silica may be due to biological utilization and its biological adsorption in the sediment as has also been reported by Ragothaman & Patil (1985) for Narmada River. Present finding are insubstantial agreement with those of Quasim & Sengupta (1981) and Qadri et.al. (1981).

The conductivity values varied from 160.00 to 790.00 μmho cm^{-1} in winter season, 170.00 to 800 μmho cm^{-1} in summer season and 140.00 to 390.00 μmho cm^{-1}in rainy seasons. The conductivity value was found 800.00 μmho cm^{-1} the maximum in summers. It may be due to increasing solubility of mineral salts with increasing temperature and low pH condition. The observation coincide with Gupta and Sharma (1994) and Kumar A(2003).

In the present study (table4.3), the values for total hardness were found to be higher during summer season at station III, IV, and VI. The hardness gradually increased form station I to station V mainly due to factory drains, carrying untreated effluents, joining at various points in between the sampling station. The effluents through the factory drains invariably contain chlorides and sulphates which increase the hardness.

The highest values were obtained at station V where the effluents of leather industries and other small industries merge into the river Ganga before sampling station V. The hardness above 200 mgL^{-1} may cause scale deposition in the process and result in excessive soap consumption and subsequent scum formation. Soft water with hardness of 100 mgL^{-1} may have low buffer capacity and may be more corrosive for water pipes, Gupta et al., (1988), Rao et al.,(1990), Sriksnth et al.,(1995).

The DO value varied from 7.20 to 9.40 mgL^{-1} in winter season 5.40 to 8.40 mgL^{-1} in summer season and 6.80 to 9.20 mgL^{-1} in rainy season. The DO level was found to be maximum 9.40 mgL^{-1} at station I during winter season, where there are less causes of pollution. The minimum value of DO was recorded 5.40 mgL^{-1} at station V in summer season, it may be attributed due to discharge of industrial effluent of leather industries and pollution load of domestic sewage of the city through Bengali nala and Burhiya nala which merge into the river Ganga before station V. The mean BOD value was found to be maximum at station V it may be due to addition of highly polluted industrial effluent. COD of any water sample remain usually higher than BOD as many more compounds can be chemically oxidized as compared to biological oxidation. In the present investigations the COD values was found to be much higher than the corresponding BOD values, effluents discharged into the river Ganga before station V. The higher values of COD than BOD also indicate that most of the pollution in river Ganga is caused by the industrial units like Ordinance Equipment Factory and leather industries. The higher values of alkalinity were found at stations IV & V which may be attributed due to industrial discharged from Ordinance Equipment Factory and leather industries into the river Ganga before stations IV & V. The maximum value of sulphate 46.20 mgL^{-1} was reported at station V in winter season. However, the minimum value of sulphate 22.00 mgL^{-1} was found at station I in rainy season.

The higher sulphate contents was observed at stations IV and V during entire course of study and in all the three seasons, which may be attributed due to regular discharge of toxic material of industrial effluents from Ordinance Equipment Factory and leather industries and domestic sewage of the area which passed into the river Ganga before stations IV and V.

Domestic and industrial effluents and agricultural run-off are the major sources of phosphorous in water, hence its concentration is indicative of pollution.

Concentration of both chloride and sulphate were not much higher showing that river water is very much suitable for agricultural purposes. The Calcium content as calcium carbonate was found to vary from 22.40 to 62.0 mgL^{-1} in winter season, 26.40 to 68.80 mgL^{-1} in summer season and 18.70 to 53.0 mgL^{-1} in rainy season. The ionic concentration of river Ganga was found in the sequence of Ca^{+2}> Mg^{+2}> Na^{+}> K^{+}.

The concentration of iron varied from 0.538 to 2.150 mgL^{-1} in winter season, 0.560 to 2.321 mgL^{-1} in summer season and 0.470 to 1.878 mgL^{-1} in rainy season.

The concentration of cadmium was found to be nil or not detectable quantitatively at stations I and II, in all the three seasons. The concentration of copper varied from 0.023 to 1.120 mgL^{-1} in winter season, 0.025 to 1.180 mgL^{-1} in summer season and 0.020 to 1.100 mgL^{-1} in rainy season. The maximum concentration of copper 1.180 mgL^{-1} was reported at station V during summer season, while the minimum concentration of copper 0.020 mgL^{-1} was found at station I in rainy season.

The concentration of lead during winter season ranged from 0.031 to 0.068 mgL^{-1}, in summer season while the minimum concentration of lead 0.030 mgL^{-1} was recorded at station I in rainy season.

The concentration of manganese for three seasons i.e., winter, summer and rainy seasons was found to vary from 0.042 to 0.152 mgL^{-1} , 0.044 to 0.184 mgL^{-1} and 0.040 to 0.116 mgL^{-1} respectively.

A few higher values were noted at stations IV and V of the sampling river Ganga, it may be due to merger of discharge of Ordinance Equipment Factory and leather industries and waste of OEF nala, Bengali nala and Burhiya nala carrying industrial effluents and sewage disposal of the city before stations IV and V.

The higher concentration of zinc was found at station IV and V in the river Ganga, it may be attributed due to regular discharge of the effluent of Ordinance Equipment Factory and leather industries. The maximum concentration of chromium 0.158 mgL^{-1} was found at station V in summer season. However, the minimum concentration of chromium 0.004 mgL^{-1} was reported at station III during rainy season. Higher concentrations of all the heavy metals were always found at stations IV & V in the river Ganga which is easily explainable by high concentration of metals brought about by the Ordinance Equipment Factory and leather industries and domestic sewage disposal of the city through OEF nala, Bengali nala and Burhiya nala and these discharge their pollution load into the river Ganga before stations IV & V.

Conclusion:

The present study attempts to highlight the main causative factors of pollution of river Ganga and to access the degree of pollution in the river.

The study may prove useful for the pollution, chemistry and biology. It can also explain usefully for managing and restoring many damaged ecosystems. The data obtained from the study will also provide the basic guide lines for the treatment of river Ganga and other water bodies.

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