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WATER QUALITY
OF
DISTRICT HARDWAR (U.P.)

आपो हि ष्टा मयोभुवः

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PREFACE

Water is a very important constituent of the ecosystem on the Earth and essential component of life. The demand of water is increasing day by day due to the increase in population and in living standard. The quality of our water resources is deteorating day by day due to the contiunouns addition of undesirable chemicals in them. Therefore, in this report, attempts have been made to determine the quality of water of district Hardwar, U.P. The importance of the work lies in the fact that the Hardwar is a very important city of Western U.P. Besides, the report contains the analysis of all available surface, ground and waste waters. In addition to this, attempts have been made to find out the possible sources of water pollution. The quality of water of district Hardwar has also been discussed in terms of physico-chemical parameters.

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DIRECTOR

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ABSTRACT

The quality of water is deteorating day by day due to the increase in population and in living standard. This decrease in water quality is due to the continuous addition of undesirable chemicals in water resources. Therefore, the preservation of water quality of the natural water resources is essential and important. In view of this the water quality of district Hardwar, U.P., an important district of western U.P., has been determined.

The physico-chemical parameters of surface, ground and waste waters of district Hardwar were determined. The total samples collected were 102 including 16, 60 and 26 samples from surface, ground and waste waters respectively. The effect of monsoon on the water quality was studied by collecting and analyzing the pre- and post-monsoon samples. The results obtained were compared with the permissible values (Indian Standards) and it was found that the water quality of surface and ground water is safe except in some cases. It has also been observed that the quality of ground water is poor in the upper zone while it become good on going down (more that 100 feet). The SAR values calculated for surface, ground and waste waters indicate that waters are of excellent and good classes by the irrigation point of view. The possible sources of water pollution have been determined and discussed. It has been observed that the main sources of pollution are municipal, industrial and agricultural activities, land disposal of solid wastes, sewage disposal on land and geochemical reactions. Finally, it has been observed that the quality of surface and ground waters of district Hardwar is good and safe. However, the quality of ground water upto 50 feet is not good.

1.0 INTRODUCTION

Water is a very important constituent of the ecosystem on the Earth and essential component of life. The demand of water is increasing day by day due to the increase in population and in living standard. The quality of our water resources is deteorating day by day due to the continuous addition of undesirable chemicals in them (L'vovich, 1979). The main sources of water contamination are industrialization, civilization, agricultural activities and other environmental and global changes. Besides, the degradation of ground water quality can take place over large areas from plane or diffused sources like deep percolation from intensively farmed fields, or it can be caused by point sources such as septic tank, garbage disposal sites, cementaries, mine spoils, oil spills or other accidental entry of pollutants into the under ground environment. In addition to all these, another possibility of contamination is by line sources of poor quality water, like seepage from polluted streams etc. Due to the slow movement of ground water, many years may elapse between start of pollution and its reflection in ground water (Bowen, 1980, Todd, 1980 and Raghunath, 1990). In this way, all these activities are destroying the quality of water and making water unfit for our use. The ground and surface waters at many of the places in the world are not suitable for drinking purpose because of the presence of different toxic pollutants. If this will be the situation all the world will be in great trouble after a few decades. Therefore, the importance of water quality preservation and improvement is essential and increasing continuously (Jain and Ali, 1997 and Ali, and Jain, 1998). Prior to use water from natural resources, the determination of water quality is the main component of hydrology. The periodical determination of water quality of our natural water resources is essential. Therefore, the determination of water quality is very important aspect by the public water supply, irrigation, industrial applications, power generation etc. point of views. The present study describes the determination of water quality of district Hardwar, UP. The selection of

district Hardwar was made due to certain important points as discussed in scope of the study section.

2.0 WATER QUALITY AND HEALTH

There are numerous compounds present in surface, ground and waste waters but the toxicity is observed beyond a certain limit called permissible limit. The type of pollutants present in different types of waters depends upon the nature of the industries, agricultural and municipal activities. The various types of water pollutants may be categorized as inorganics, organics, and biologicals in nature (Table 1). The most common water pollutant inorganics are heavy metals which are highly toxic and carcinogenic in nature. Besides, some of the anions such as nitrate, sulphate, phosphate, fluoride, chloride, oxalate etc. have also some serious hazardous effects. The toxic organic pollutants include pesticides, phenols, biphenyls, detergents, oils, greases etc. In addition to these, hydrocarbons, alcohols, aldehydes, ketones, proteins, lignin, pharmaceuticals etc. found in wastewater may also be harmful. The different types of microbes present in wastewater may be responsible for various type of diseases. The harmful microbes are bacteria, fungi, algae, planktons, amoeba, virus and other worms. These water pollutants remain either in soluble, colloidal or in suspended form. The different types of major diseases and side effects produced by these toxic pollutants are summarized in Table 1 (Gaston, 1979, Hutson, and Roberts, 1990, John., 1990, Tchobanoglous, and Franklin, 1991 and LaGrrega, et al. 1994).

Table 1: Diseases and Side Effects due to Different Water Pollutants

Water Pollutants	Diseases/Side Effects
1. Inorganics	
Metal Ions	Carcinogenic
Nitrate	Vasodilatory/Cardiovascular effects and Methemoglobinemia
Sulphate	Diarrhea, gastroenteritis (in infants) and dehydration
Fluoride	Dental fluorosis, asymptomatic osteosclerosis
Oxalate	Kidney problem
Cyanide	Poisonous
2. Organics	
Pesticides	Cracinogenic
Phenols	Carcinogenic
Biphenyls	Carcinogenic
Detergents	Carcinogenics
Oils	Carcinogenics
Grease	Carcinogenics
3. Biologicals	
Bacteria	Cholera, typhoid, dysenteries, diarrhea, enteritis, diphtheria
Fungi	Intestinal infections
Protzons	Amebic dysentery and hepatitis, giardiasis
Nematodes	Helmints and digestive disturbance
Algae	Nuisance and odor problem
Planktons	Nuisance and odor problem
Virus	Gastroenteritis, hepatitis, meningitis, paralysis, myocarditis, diarrhea and viral fever

3.0 SCOPE OF THE STUDY

The present study describes the water quality of district Hardwar, U.P. The district Hardwar is a famous and holy city of India where millions of pilgrims visited ever year which may be treated as the extra pollution load in the district itself. Besides, the Shiwalik mountain in north are making water hard. In addition to this, the increase of industrialization, garbage disposal, septic tanks, cementaries, oil spills, agricultural and domestic activities are also alarming problems for water contamination. In view of all these points, the district Hardwar was selected for the water quality study.

The main aim of the study includes:

1. To see the regional water quality variation within the district.
2. The pre- and post monsoon water quality variation.
3. The effect of industrialization, civilization, agricultural activities and other environmental effects on water quality.
4. To find out ground water quality at different depths.
5. To determine the possible pollution sources.

4.0 STUDY AREA

The present study comprises total area of district Hardwar. The total area of the district is 1994.0 km^2. The district Hardwar lies between 77°35' to 78°15' latitude and 29°35' to 30°03' longitude (Fig. 1). The detail of the district in terms of its boundary, rivers, canals and sampling points (surface, ground and waste waters) is shown in Fig. 2. The district Hardwar is a very famous city of India where a large number of pilgrims use water ever year. Besides, the district Hardwar is situated just beneath the Shiwalik mountain ranges making ground water hard. In addition to this, the slow increase of industrialization even at small scale, agricultural and domestic activities are also alarming problems for the maintenance of water quality. The detail of the district is discussed below.

4.1 Physiography

The area of Hardwar is plain except the presence of Shiwalik mountain range in north (Hardwar city itself). There is no void features except that the presence of rivers and nallas. The district is bound by Shiwalik ranges and river Ganga at north and east respectively.

4.2 Drainage

Most of the river of Hardwar district are flowing from west to east. The rivers are ephemeral in nature. However, water from groundwater storage flow round the year. The most important rivers of Hardwar are Ganga, Solani, and Ratmau. Besides these river, the Ganga canal flow from north to south. The Ganga canal receive its water from Ganga itself at Hardwar.

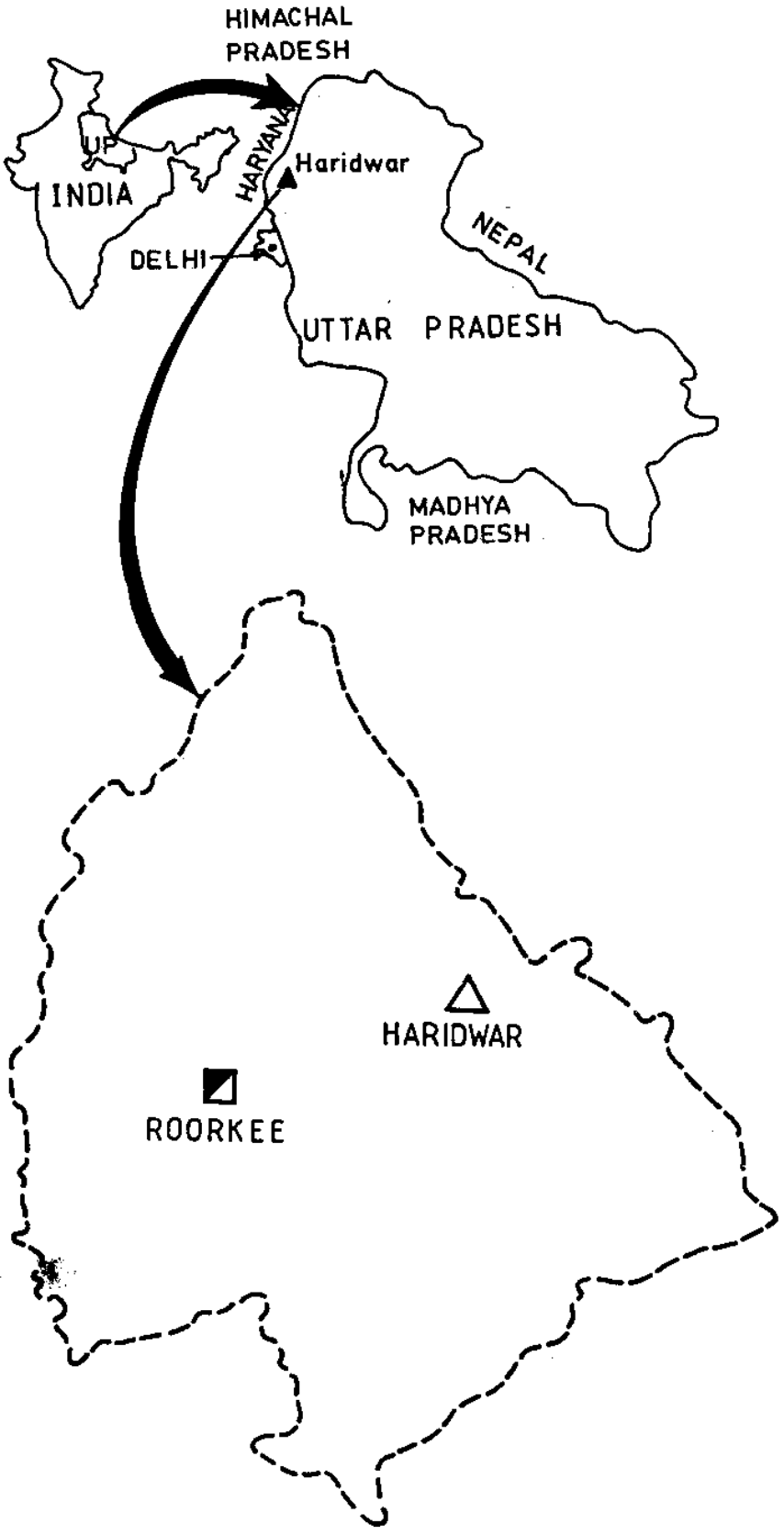

FIG.1 : LOCATION OF DISTRICT HARIDWAR

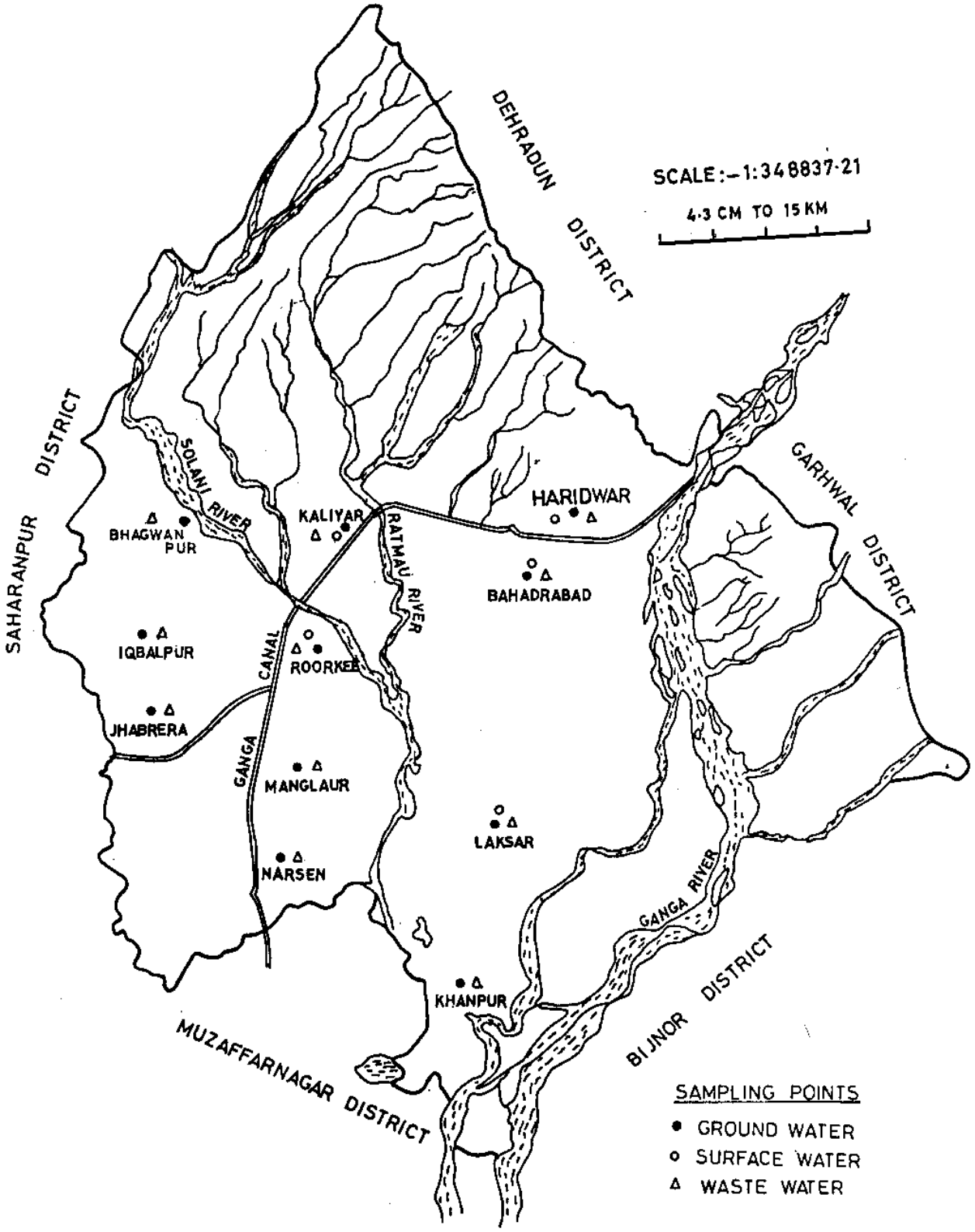

FIG.2 :LOCATION OF SITES OF SURFACE, WASTE AND GROUND WATER SAMPLES IN HARIDWAR DISTT.

4.3 Climate

The district Hardwar comprises the moderate type of subtropical monsoonic climate. The average monsoon rain fall in the district is about 50 cm. The major rain fall is received in monsoon season. The density of rainfall decreases from north to south. The temperature ranges from 8 to 16°C in winter and 25 to 45°C in summer respectively.

4.4 Geology

The district Hardwar is a part of west Indogangetic plain which is composed of Pleistocene and subrecent alluvium material brought down by rivers from the Himalayan region. The alluvium is made of sand, silt, clay, kankar and garavel. The deposits of sand beds are the main source of groundwater in the district.

4.5 Geohydrology

The groundwater conditions in the reported area are influenced by the varying lithology of the subsurface formation. It has been observed that the strata exhibit great variation both laterally and vertically due to the general fluviatile nature of the deposit of Indogangetic plain. The main source of the ground sand bed is the monsoon rain fall. However, replenishment is also obtained by infiltration due to rivers, canal, ponds, irrigation etc. The most common groundwater utilization is achieved by hand pumps and tube wells. Two types of aquifer have been reported in the area (Singh, et al. 1979). The upper one is the shallow unconfined aquifer which generally extends to depths around 25 m. The deeper one is confined to semi confined in nature and located at depth about 25 to 150 m, below ground level separated by three to four aquifers at average depths of 25 to 55 m, 65 to 90 m and 120 to 150 m. Water table contours in the area indicate the southward trend of ground water flow both in unconfined and confined aquifers.

4.6 Flora and Fauna

A variety of herbs and Serbs are found in the district. Among the trees, Sesam, Sagaun, Babul, Aam (mango) are the most common. The animals found in the district include Fox, Jackal and Squirrels. The wolf, Hyena and wild cats are also found. The most common birds are black Partridge, Jack Shipe, Duch, Goose etc. The poisonous variety of snakes including Cobra and Kraites are also found.

4.7 Crops, Land Use and Irrigation Patterns

The important crops are sugar cane, wheat, rice, barley, gram, maize, mustard etc. The crops are grown normally in Rabi and Kharif seasons. The land is used for agriculture is plain and the ploughing is done either by oxen or tractors. The method of irrigation is purely by tube well. The canal and river irrigation is rarely used. The tube wells are driven either by diesel engine or electricity.

4.8 Mineral Resources

The foundry sand is found in the rivers of the district. It is a high grade silica sand left behind the change in the course of the rivers. It is used for the construction of buildings, dams, bridges etc. Some of the Shiwalik ranges are used as the source of calcium carbonate. The calcium carbonate is used again as the building material and also used in the Sugar Mill for the production of sugar.

4.9 Industries

The district Hardwar is not the main center/district for industrial point of view. However, a Sugar Mill is situated at Iqbalpur while B.H.E.L. at Ranipur is the famous factory in India. The city Hardwar has an abundance of the Ayurvedic small scale industries. Besides these, the other small scale industries such as Kraisher, Steel, Agro and Food processing etc. units are also found in the district.

5.0 EXPERIMENTAL

5.1 Chemicals and Reagents

All the chemicals and reagents used were of analytical grade and were procured from E. Merck, India and BDH, India.

5.2 Instruments Used

In addition to the normal glasswares, the other instruments used for the study are given in Table 2. The standard supplied manuals with the instruments were followed for using them.

5.3 Sampling and their Preservation

The pre- (May 1998) and post-monsoon (October 1998) water samples were collected. The grab samples of surface, ground and waste waters were collected from different points in Hardwar district. The total water sample collected (pre-monsoon) were 102 including 16 of surface, 60 of ground and 26 of waste waters respectively. The same set of sampling was done in post-monsoon season. The detail sampling points are shown in Fig. 2. Some of the physical parameters such as temperature, pH, conductivity, turbidity etc. were measured at the site itself while the other parameters were studied in the Laboratory. The preservation of the samples was done as given in Table 3.

5.4 Analysis of Water Samples

The standard solutions of the chemicals were prepared in double distilled water while the standard samples for Atomic Absorption Spectrometer (AAS) were purchased from E. Merck, Germany. The Instruments were first calibrated with the known standard solutions

Table 2. List of Equipment Used

Sl. No.	Parameters	Instrument/Equipment
1.	pH	pH meter
2.	Conductivity	Conductivity meter
3.	Turbidity	Turbidity meter
4.	Nitrate, Phosphate and Sulphate	UV-Vis Spectrometer
5.	BOD	BOD Incubator
6.	Heavy Metals	Atomic Absorption Spectrometer (AAS)

Table 3. Methods of Water Samples Preservation

Sl. No.	Parameters	Preservatives	Maximum Storage Time
1.	Color	Cool to 3-4°C	24 hrs.
2.	Residue	Cool to 3-4°C	24 hrs.
3.	Turbidity	Cool to 3-4°C	7 days
4.	pH	--	Immediately
5.	Acidity	Cool to 3-4°C	24 hrs.
6.	Alkalinity	Cool to 3-4°C	24 hrs.
7.	Hardness	Add 2mL HNO_3/L Cool to 3-4°C	7 days
8.	Sulfate	Cool to 3-4°C	7 days
9.	Chloride	--	7 days
10.	Dissolved Oxygen	Collect in BOD Bottle	Immediately
11.	Phosphate	Cool to 3-4°C	24 hrs.
12.	Nitrate	Cool to 3-4°C	7 days
13.	B.O.D.	Cool to 3-4°C	6 hrs.
14.	C.O.D.	Add 2 mL H_2SO_4/L	7 days
15.	Metals	Add 2 mL HNO_3/L	6 months

and then were used to find out the concentration of the specific physico-chemical parameters. The various parameters analyzed are summarized in Table 4, 5 and 6 for surface, ground and waste waters respectively. The standard procedures for the analysis of these physico-chemical parameters were followed (US, EPA Report, 1974, Clesceri, et al. 1981 and Adams, 1990)

6.0 RESULTS AND DISCUSSION

The results obtained by the analysis of the samples collected from district Hardwar are given in Table 4, 5 and 6 for surface, ground and waste waters respectively. The results of pre- and post monsoon seasons are also described in these Tables. The studied parameters are Color, Odor and Taste, Temperature, pH, Turbidity, Conductivity, Total Dissolved Solids (TDS), Hardness, Alkalinity, Chloride, Sulphate, Nitrate, Phosphate, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Sodium, Potassium, Calcium, Magnesium, Cadmium, Lead, Copper, Iron, Cobalt and Chromium. The Sodium Adsorption Ratio (SAR) was also calculated for surface, ground and waste water samples. The concentration of all these parameters is expressed in mg/L while the unit of conductivity and temp. are μS/cm and °C respectively. There is no unit of SAR as it is a ratio. The results of the various parameters and their variation with respect to pre- and post monsoon seasons, depth etc. are described below.

6.1. Color

The color of water may be due the presence of metallic ions, humus, peat materials and industrial waste. The surface and ground water were colorless while the color of wastewater of municipal discharges was mostly black while the color of industrial drains was brown. There was no change in the color of surface and ground water in the pre- and the post-monsoon seasons while the color of wastewater become light in post monsoon season. The color of the Iqbalpur Sugar Mill was varied from dark yellow to brown.

6.2. Odor and Taste

The surface and ground water samples were odorless while the unpleasant odor was found in waste water. The surface and ground water samples were with agreeable taste with

Table 4: Physico-chemical Data of Surface Water of District Hardwar

Sl.No	Name of the Site	Color	Odor & Taste	Temp C	pH	Turbidity NTU	EC uS/cm	TDS mg/L	Hard mg/L	Alk mg/L	Cl mg/L	SO4 mg/L	NO3 mg/L	PO4 mg/L	DO mg/L	BOD mg/L	COD mg/L	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	Cd mg/L	Pb mg/L	Cu mg/L	Fe mg/L	Co mg/L	Cr mg/L	SAR
1	Hardwar		Odorless & Agreeable																									
	CWa	Colorless	Odorless & Agreeable	22.5	7.8	0.1	133	85.1	74	58	72.4	24	1.3	0.3	8.5	7	10	33.7	5.4	23.3	3.9	0.006	0.923	0.018	5.236	ND	ND	9.1
	CWb	Colorless	Odorless & Agreeable	15	8.2	4	204	130	106	220	4	27.5	0.4	0.07	9.8	5.7	8.1	33.4	5.9	72	6.8	0.012	0.033	0.002	0.42	0.002	ND	5.3
	RWa	Colorless	Odorless & Agreeable	22	7.8	40	131	85	75	58	40.5	24.1	1.4	0.3	8.9	7	10	33	5	23.5	3.9	0.005	0.92	0.015	5.24	ND	ND	8.2
	RWb	Colorless	Odorless & Agreeable	14	7.9	104	200	120	109	30	75.3	29	0.5	0.07	10	7	12	37.2	5.1	35	8	0.002	0.081	ND	0.291	ND	ND	8.2
2	Bahadrabad		Odorless & Agreeable																									
	CWa	Colorless	Odorless & Agreeable	22	7.8	100	135	84.1	75	57	76.3	24	1.3	0.3	8.4	7.2	10.3	33.5	5.4	24	3.9	0.006	0.923	0.018	5.24	ND	ND	9
	CWb	Colorless	Odorless & Agreeable	15	8	4	205	131	110	125	40.1	2.6	0.4	0.06	9.04	7	10	36.1	4.9	31.5	5	0.001	0.05	ND	0.285	ND	ND	8.5
3	Kaliyar		Odorless & Agreeable																									
	CWa	Colorless	Odorless & Agreeable	21.4	7.9	106	128	82	70	64	6	10	1.3	0.1	8.6	6.4	9.1	8	2.6	22.5	3.4	0.003	0.187	0.011	0.77	ND	ND	22
	CWb	Colorless	Odorless & Agreeable	14.5	7.4	5	205	131	96	100	37.6	27.5	ND	0.02	10	5.5	7.9	36.4	4.9	25.7	7.8	0.001	0.052	0.01	0.295	ND	ND	8.9
4	Roorkee		Odorless & Agreeable																									
	CWa	Colorless	Odorless & Agreeable	21.5	8	106	138	88	80	72	5	21.5	1.3	0.1	8.5	6.3	9	14.7	3.1	21.7	6.3	0.001	0.63	0.008	0.677	ND	ND	3.9
	CWb	Colorless	Odorless & Agreeable	14.7	7.2	6	212	136	100	90	73.1	27.5	0.6	0.08	10	5.3	7.5	42	5.3	27.3	7.8	ND	0.079	0.006	0.89	0.005	ND	12.9
	RWa	Colorless	Odorless & Agreeable	28.8	8	40.2	408	264	188	220	42.6	4	0.7	0.18	7.2	6.3	9.2	47.9	4.6	52.9	13.6	ND	0.027	ND	1.207	ND	ND	6.3
	RWb	Colorless	Odorless & Agreeable	19.8	7.6	73	435	278	190	220	4	16.5	6.2	0.27	6.2	5.6	7.9	55	4	56	4.9	0.005	0.564	0.062	1.45	ND	ND	10
5	Laksar		Odorless & Agreeable																									
	RWa	Colorless	Odorless & Agreeable	22.5	7.9	41	135	86	77	59	76.3	24.5	1.4	0.52	8.7	7.7	11	34	6	24	3.8	0.005	0.987	0.016	6.12	ND	ND	9.1
	RWb	Colorless	Odorless & Agreeable	15	7	110	210	125	110	182	4.2	26.1	1	0.8	10.5	8.8	12.5	35	5	36	6.8	ND	0.048	ND	0.295	ND	ND	8.2
6	Khanpur	Surface Water is Not Available																										
7	Gurukul Narsan	Surface Water is Not Available																										
8	Mangiore	Surface Water is Not Available																										
9	Jhabrera	Surface Water is Not Available																										
10	Iqbalpur	Surface Water is Not Available																										
11	Bhagvanpur																											
	RWa	Colorless	Odorless & Agreeable	28.8	8	40	407	260	190	225	78.1	4.1	8	0.17	7.2	8.4	9.2	55	5	53	14	0.005	0.55	0.062	1.49	ND	ND	9.5
	RWb	Colorless	Odorless & Agreeable	20	7.7	74	440	280	191	220	8	16	6.2	0.3	6.5	5.6	8	48	4.8	55	8	ND	0.047	ND	0.3	ND	ND	8.7

CW : Cannal Water , RW River Water , a: Pre Monsoon Samples , b:Post Monsson Samples ,EC: Electrical Conductivity ,TDS : Total Dissolved Solids , DO:Dissolved Oxygen, BOD: Biological Oxygen Demand , COD: Chemical Oxygen Demand , SAR: Sodium Adsorption Ratio and ND: Not Detected

Table 5: Physico-chemical Data of Ground Water of District Hardwar

Sl.No	Name of the Site	Color	Odor & Taste	Temp C	pH	Turbidity NTU	EC uS/cm	TDS mg/L	Hard mg/L	Alk mg/L	Cl mg/L	SO4 mg/L	NO3 mg/L	PO4 mg/L	DO mg/L	BOD mg/L	COD mg/L	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	Cd mg/L	Pb mg/L	Cu mg/L	Fe mg/L	Co mg/L	Cr mg/L	SAR
1	Hardwar																											
	Aa	Colorless	Odorless & Agreeable	25.5	7.9	8	560	341	300	290	8.2	39.9	5.5	0.21	1.1	9.7	13.9	39.9	10.2	73.3	21.9	0.007	ND	ND	0.013	ND	ND	6.8
	Ab	Colorless	Odorless & Agreeable	17.1	7.8	5	577	345	310	281	8.9	40.0	5.4	0.2	1.2	10.2	14.5	39.4	10.0	72.5	22.0	0.008	ND	ND	0.015	ND	ND	5.7
	Ba	Colorless	Odorless & Agreeable	25.1	7.6	2.9	510	320	269	250	6.1	35.0	5.0	0.15	1.5	8.4	12	35.1	9.2	69.3	20.3	0.005	ND	ND	0.012	ND	ND	5.2
	Bb	Colorless	Odorless & Agreeable	18	7.5	2.8	500	319	251	240	6.0	35.8	5.1	0.15	1.1	8.6	12.5	35.0	9.0	68.5	20.1	0.006	ND	ND	0.013	ND	ND	5.7
	Ca	Colorless	Odorless & Agreeable	24.3	7.6	1.2	480	307	232	230	5.0	32.5	4.2	0.14	1	7.7	11	30.3	7.0	61.8	19.0	0.005	ND	0.007	0.005	ND	ND	4.8
	Cb	Colorless	Odorless & Agreeable	19.1	7.4	3	269	172	122	116	7.0	27.5	1.2	0.16	1	9	12.6	30.5	4.0	36.1	7.8	0.004	0.075	0.004	0.248	ND	ND	6.51
2	Bahadrabad																											
	Aa	Colorless	Odorless & Agreeable	22	8.5	4	521	490	200	150	75.0	20.0	2.9	0.05	1	7.5	10.1	5.0	2.0	60.0	15.0	0.005	0.2	0.08	0.712	ND	ND	0.8
	Ab	Colorless	Odorless & Agreeable	19	8	4	501	470	200	140	53.8	18.0	2.0	0.06	1	7.5	11	5.1	1.5	55.0	14.0	0.004	0.2	0.01	0.7	ND	ND	0.9
	Ba	Colorless	Odorless & Agreeable	23.2	8.2	2.4	492	319	140	136	40.0	15.0	2.2	0.04	1.4	5.5	7.9	4.5	1.6	40.1	9.7	0.004	0.189	0.009	0.839	ND	ND	0.9
	Bb	Colorless	Odorless & Agreeable	20.3	7.8	11	601	385	260	234	70.5	31.5	4.8	0.09	1.5	5.7	8.3	10.3	31.2	81.0	14.1	ND	0.028	0.007	1.411	ND	ND	4.5
	Ca	Colorless	Odorless & Agreeable	23.6	8.5	1.9	471	301	226	134	17.0	40.0	2.2	0.02	1	13	20	46.0	3.5	72.2	11.2	0.006	0.118	0.011	0.213	ND	ND	7.13
	Cb	Colorless	Odorless & Agreeable	15.5	6.4	2	470	300	178	170	18.0	13.5	0.9	0.06	1	5.8	24.3	12.2	2.8	18.9	13.6	0.001	0.088	0.102	0.087	ND	ND	3
3	Kaliyar		Odorless & Agreeable																									
	Aa	Colorless	Odorless & Agreeable	24.1	7.7	26	1141	710	240	180	5.0	45.0	20.1	0.3	3	7.8	10	4.5	5.9	45.2	37.1	0.015	0.091	0.015	0.5	ND	ND	0.7
	Ab	Colorless	Odorless & Agreeable	20	7.6	25	1121	700	230	181	4.8	44.0	20.0	0.29	1.1	8.4	12	4.4	8.8	45.0	36.1	0.015	0.09	0.014	0.5	ND	ND	0.7
	Ba	Colorless	Odorless & Agreeable	24.1	7.6	24.4	1103	706	230	172	4.7	42.5	19.0	0.28	1	5.6	8.1	4.2	5.8	34.5	35.0	0.011	0.085	0.012	0.489	ND	ND	0.71
	Bb	Colorless	Odorless & Agreeable	22.6	6	12	1256	804	544	474	4.4	48.0	11.8	0.09	1	8.3	9.1	10.2	30.2	20.5	10.7	ND	0.024	0.003	0.96	ND	ND	2.6
4	Roorkee																											
	Aa	Colorless	Odorless & Agreeable	24.6	7.6	1.4	449	287	214	178	70.0	14.0	1.0	0.03	1.6	3	4.1	32.4	0.5	53.7	19.4	0.008	0.033	0.019	4.833	ND	ND	5.4
	Ab	Colorless	Odorless & Agreeable	22.5	8.1	4	418	268	220	214	68.0	19.5	0.4	0.07	1.9	5.9	0.1	62.8	5.4	81.8	16.0	NO	0.057	ND	0.461	ND	ND	10.1
	Ba	Colorless	Odorless & Agreeable	25	7.5	1	431	280	200	161	48.6	11.0	0.9	0.02	1.7	2.7	3.8	30.0	0.4	50.1	18.2	0.004	0.03	0.013	4.1	ND	ND	5.1
	Bb	Colorless	Odorless & Agreeable	20.1	7.5	1	430	270	201	158	49.3	12.0	0.9	0.02	1.7	2	3.5	31.0	0.4	50.0	18.0	0.004	0.03	0.015	4.1	ND	ND	5.3
	Ca	Colorless	Odorless & Agreeable	27.3	8.1	1	442	283	200	224	47.6	19.0	1.3	0.6	1.7	1.2	15.6	47.0	4.8	50.3	18.0	0.006	0.092	0.021	12.5	ND	ND	8
	Cb	Colorless	Odorless & Agreeable	19.8	8	3	467	299	205	230	52.2	19.0	1.7	0.12	1	1.2	17	47.5	5.2	48.1	16.9	ND	0.091	0.003	0.079	ND	ND	8.3
5	Laksar																											
	Aa	Colorless	Odorless & Agreeable	24	7	15	1210	810	550	301	151.0	31.0	1.9	0.06	2	7.6	11	15.1	1.2	190.0	25.1	0.109	ND	0.009	3.81	0.005	ND	1.5
	Ab	Colorless	Odorless & Agreeable	14.1	7.1	14.9	1729	815	555	301	150.9	30.0	1.8	0.05	2	7.8	11.5	14.0	1.0	180.2	24.8	0.104	ND	0.009	3.81	0.005	ND	1.4
	Ba	Colorless	Odorless & Agreeable	25	7.1	10	1129	722	500	278	138.1	28.0	1.5	0.04	1.5	6.2	9.1	11.7	1.0	160.0	24.3	0.104	ND	0.008	3.661	0.004	ND	1.2
	Bb	Colorless	Odorless & Agreeable	22.9	7.8	53	1147	734	480	458	56.0	33.5	ND	0.09	1.8	7.7	10.7	12.2	10.8	76.4	9.7	ND	0.028	0.012	4.989	ND	ND	1.9
	Ca	Colorless	Odorless & Agreeable	25	7.4	26.2	1169	748	420	364	17.0	25.0	0.7	0.05	1.1	8.5	12.3	11.7	18.6	13.8	19.4	0.007	0.059	0.011	1.072	ND	ND	2.9
	Cb	Colorless	Odorless & Agreeable	22.5	7.4	7	680	435	300	344	18.0	20.0	ND	0.1	1.5	8	13.1	11.8	5.1	80.2	24.3	ND	0.015	0.003	1.359	ND	ND	1.6
6	Khanpur																											
	Aa	Colorless	Odorless & Agreeable	26.4	8.4	4.3	490	282	110	140	10.0	10.0	1.0	0.05	1.5	4.6	6.9	9.7	0.6	42.0	9.7	0.002	ND	0.006	1.123	0.002	ND	2.1
	Ab	Colorless	Odorless & Agreeable	23.2	7.9	5	492	315	134	206	10.0	7.5	1.7	0.15	2.1	4.7	7.4	40.0	3.5	34.5	11.7	ND	0.053	0.002	0.879	ND	ND	8.3
	Ba	Colorless	Odorless & Agreeable	25.1	7.4	4	410	261	100	230	5.0	8.2	0.7	0.03	0.9	3.7	5.5	8.2	0.4	66.0	8.6	0.002	ND	0.006	1.1	0.001	ND	1.3
	Bb	Colorless	Odorless & Agreeable	19.1	7.4	4	420	268	110	240	5.5	8.1	0.7	0.03	1	4	8.1	9.0	0.4	66.0	8.5	0.002	ND	0.006	1.1	0.001	ND	1.5

Cont...

Table 5 Contd..

Sl.No	Name of the Site	Color	Odour & Taste	Temp C	pH	Turbidity NTU	EC uS/cm	TDS mg/L	Hard mg/L	Alk mg/L	Cl mg/L	SO4 mg/L	NO3 mg/L	PO4 mg/L	DO mg/L	BOD mg/L	COD mg/L	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	Cd mg/L	Pb mg/L	Cu mg/L	Fe mg/L	Co mg/L	Cr mg/L	SAR
7	Gurukul Narsan																											
	Aa	Colorless	Odorless & Agreeable	25	8.4	2.3	231	148	125	235	30.0	31.0	1.3	0.14	1.1	4.1	6	2.7	2.2	75	24.3	ND	0.111	0.003	0.266	ND	ND	0.4
	Ab	Colorless	Odorless & Agreeable	23.7	7	3	233	149	120	110	10.2	27.5	0.8	0.05	1.3	4.2	6.7	7.1	6.3	24.1	14.6	ND	0.042	0.005	0.229	ND	ND	1.6
	Ba	Colorless	Odorless & Agreeable	25	8	2	210	130	120	228	25.0	74.0	1.0	0.1	1.1	3.3	5	2.5	2	65	23	ND	0.1	0.001	0.208	ND	ND	0.4
	Bb	Colorless	Odorless & Agreeable	21.1	7.7	2.1	211	131	118	227	26.0	26.0	0.9	0.1	1.5	4	5.9	2.5	2	78.6	23.2	ND	0.1	0.001	0.201	ND	ND	0.3
	Ca	Colorless	Odorless & Agreeable	25.8	7.3	1.7	317	203	142	132	10.0	25.0	2.0	0.005	2	4.6	7.5	3.2	0.4	40.1	10.2	0.005	ND	0.04	0.208	ND	ND	0.6
	Cb	Colorless	Odorless & Agreeable	27.8	7.1	5.5	233	149	168	152	8.0	30.0	2.0	0.05	1.4	5.5	8.3	7.2	0.6	44.9	13.6	0.001	0.027	0.004	0.194	ND	ND	1.3
8	Manglore																											
	Aa	Colorless	Odorless & Agreeable	25.1	7.5	3	1361	855	420	305	13.0	11.6	0.1	0.2	1.1	10.3	15	15.5	3.9	131	29.5	0.005	0.51	0.005	0.71	0.005	ND	1.7
	AB	Colorless	Odorless & Agreeable	22	7.5	3.1	1370	850	425	310	25.0	11.0	0.5	0.2	1.2	10.1	14.9	15	3.8	130	25.5	0.005	0.41	0.005	0.71	0.005	ND	1.7
	Ba	Colorless	Odorless & Agreeable	24	7.3	1.1	1303	834	412	280	19.0	10.0	0.7	0.1	1.7	8.3	12	15.8	3.3	120.3	27.2	0.005	0.54	0.005	0.8	0.003	ND	1.8
	Bb	Colorless	Odorless & Agreeable	21.8	7.7	4	1312	840	440	380	11.2	9.0	0.8	0.02	1.2	8.9	14	3.5	3.2	148.3	7	ND	0.05	0.003	0.314	ND	ND	0.4
	Ca	Colorless	Odorless & Agreeable	30.8	7.5	2	565	352	270	179	15.0	30.0	0.4	0.05	1.2	6.8	9.8	8.1	5.3	64.2	51.2	ND	0.06	0.002	0.126	ND	ND	1.1
	Cb	Colorless	Odorless & Agreeable	28.6	7.8	3	578	370	401	209	14.0	40.0	0.5	0.07	1.1	7.5	10.8	15.1	1.5	87.4	60.4	ND	0.022	0.008	0.03	ND	ND	1.8
9	Jhabrera																											
	Aa	Colorless	Odorless & Agreeable	25	7.5	5	880	560	400	208	96.0	45.5	0.9	0.05	1.2	5.5	8.5	15	1.4	99.5	24.8	ND	ND	0.003	1.6	ND	ND	1.9
	Ab	Colorless	Odorless & Agreeable	19.1	7.6	5.1	870	550	344	192	91.0	45.0	0.9	0.05	1.5	6	8.8	10.9	1.4	99	24.6	ND	ND	0.006	1.6	ND	ND	1.4
	Ba	Colorless	Odorless & Agreeable	16.1	7.9	6	828	520	254	172	70.0	46.0	0.7	0.23	1.55	4.9	7.5	4.9	2.1	92.2	20.4	ND	ND	0.006	1.551	ND	ND	0.7
	Bb	Colorless	Odorless & Agreeable	20.4	8	6	768	531	583	248	118.0	50.0	0.9	0.3	1.5	5.5	7.4	12.9	2.3	144.3	47.3	ND	0.051	ND	4.528	ND	ND	1.3
	Ca	Colorless	Odorless & Agreeable	26	7.4	7	610	288	118	152	20.0	15.0	0.6	0.02	1.5	1.7	7	9.8	0.9	40.1	34.9	ND	ND	ND	0.102	ND	ND	1.4
	Cb	Colorless	Odorless & Agreeable	17.7	7.2	3	813	286	168	163	60.0	30.0	0.5	0.02	1.6	5.5	8.3	8.5	6.1	44.9	26	ND	0.074	ND	0.329	ND	ND	1.4
10	Iqbalpur																											
	Aa	Colorless	Odorless & Agreeable	26.1	7.3	8	810	550	341	290	30.0	29.9	2.5	0.05	2	6.8	10	7	0.8	109	20.1	ND	ND	0.003	3.42	ND	ND	0.9
	Ab	Colorless	Odorless & Agreeable	22	7.2	6.1	801	555	340	289	33.0	30.1	2.4	0.05	2	7	11.5	7.2	0.8	112	20	ND	ND	0.003	3.41	ND	ND	0.9
	Ba	Colorless	Odorless & Agreeable	25.7	7.2	7	787	504	310	228	20.0	23.5	2.0	0.04	2	5.4	8	8.3	0.8	96.2	17	ND	ND	0.002	3.265	ND	ND	0.8
	Bb	Colorless	Odorless & Agreeable	23.4	7.9	8	830	531	390	350	44.0	28.0	0.8	0.05	2	5.6	8.7	8.5	32.1	126.7	18	ND	0.05	ND	0.689	ND	ND	1
11	Bhagvanpur		Odorless & Agreeable																									
	Aa	Colorless	Odorless & Agreeable	26.1	7.4	4.9	510	319	241	291	70.0	5.5	1.4	0.03	2	6.8	10.1	7.2	0.6	55.5	54.7	ND	ND	ND	0.51	ND	ND	1
	Ab	Colorless	Odorless & Agreeable	23.1	7.4	4.8	512	320	240	290	72.0	5.5	1.4	0.03	2	7.2	11.2	7.5	0.5	55	54.4	ND	ND	ND	0.5	ND	ND	1.2
	Ba	Colorless	Odorless & Agreeable	25.6	7.3	3.1	484	309.8	228	240	50.0	5.1	1.3	0.01	1.6	5.4	8.1	6.9	0.5	51.3	36.5	ND	ND	ND	0.402	ND	ND	1
	Bb	Colorless	Odorless & Agreeable	23.2	8	10	518	332	250	300	64.0	3.5	ND	0.06	1.5	8	4.12	7.9	3.5	70.6	42.3	ND	0.03	ND	1.108	ND	ND	1.1
	Ca	Colorless	Odorless & Agreeable	26.3	7.2	1.6	860	550	342	264	52.0	20.0	2.0	0.02	1.3	7.6	3.5	7.49	0.6	58.2	23.4	ND	ND	0.016	0.182	ND	ND	1.2
	Cb	Colorless	Odorless & Agreeable	22.9	7.5	4	511	327	360	288	35.0	5.0	0.8	0.05	1.7	8.1	3	9.3	7.4	52.1	37.6	ND	0.023	ND	0.148	ND	ND	1.4

A:Ground Water upto 50 Feet , B: Ground Water upto 100 Feet , C: Ground Water More than 100 Feet , a: Pre Monsoon Samples , b: Post Monsoon Samples , EC: Electrical Conductivity , TDS: Total Dissolved Solids , DO: Dissolved Oxygen , BOD: Biological Oxygen Demand , COD: Chemical Oxygen Demand , SAR: Sodium Adsorption Ratio and ND: Not Detected.

Table 6: Physico-chemical Data of Waste Water of District Hardwar

Sl.No	Name of the Site	Color	Odor & Taste	Temp C	pH	Turbidity NTU	EC uS/cm	TDS mg/L	Hard mg/L	Alk mg/L	Cl mg/L	SO4 mg/L	NO3 mg/L	PO4 mg/L	DO mg/L	BOD mg/L	COD mg/L	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	Cd mg/L	Pb mg/L	Cu mg/L	Fe mg/L	Co mg/L	Cr mg/L	SAR
1	Hardwar																											
	MWa	Black	Unpleasent	26.2	8.2	21.1	1455	431	328	280	116.4	49.5	5.1	0.56	1.2	6.8	10.0	41.2	1.1	81.0	18.0	0.004	0.056	0.011	0.359	ND	ND	5.8
	MWb	Black	Unpleasent	20.1	7.0	20.0	737	472	300	290	71.4	80.0	0.6	0.23	3.4	12.2	18.8	86.0	6.4	88.2	10.4	ND	0.119	ND	0.253	ND	ND	12.2
	IWa	Brown	Unpleasent	26	7.0	15.0	839	380	350	300	113.6	50.0	1.5	0.2	1.9	8.3	12.0	95.0	1.9	105.0	18.0	0.004	0.06	0.015	0.41	ND	ND	12.1
	IWb	Brown	Unpleasent	20	7.1	16.0	850	389	340	290	148.0	55.0	1.7	0.21	2	7.3	11.0	96.0	2.0	110.0	20.0	0.005	0.07	0.02	0.419	ND	ND	11.9
2	Bahadrabad																											
	MWa	Black	Unpleasent	22.7	7.8	8.1	1127	723	322	140	100.9	60.0	2.0	0.66	ND	55.9	93.2	10.8	6.1	42.2	23.3	0.011	0.085	0.002	0.489	ND	ND	2
	MWb	Black	Unpleasent	16.5	6.7	7.0	1412	204	322	240	126.0	73.0	1.6	0.06	ND	61.8	103.5	18.0	26.2	95.4	20.4	0.008	0.109	0.018	4.452	ND	ND	2.4
3	Kaliyar																											
	MWa	Black	Unpleasent	29	7.0	15.0	1101	415	315	140	105.0	25.0	1.9	0.1	ND	18.9	29.0	5.0	1.0	96.5	1.9	0.1	0.08	0.011	0.452	ND	ND	0.7
	MWb	Black	Unpleasent	0.017	6.9	16.0	1059	400	301	130	104.0	26.0	1.6	0.1	ND	16.9	26.0	5.0	1.0	95.5	1.8	0.11	0.08	0.01	0.45	ND	ND	0.7
4	Roorkee																											
	MWa	Black	Unpleasent	28	7.0	24.0	1087	695.7	280	206	101.9	29.0	2.0	0.65	ND	30.0	5.0	12.4	2.1	75.0	10.3	0.005	0.564	0.062	1.45	ND	ND	1.9
	MWb	Black	Unpleasent	19	7.5	37.0	1066	652	290	210	68.0	34.0	4.5	0.91	ND	32.6	50.3	11.9	4.7	84.2	10.4	ND	0.077	0.04	0.973	ND	ND	1.7
5	Laksar																											
	MWa	Black	Unpleasent	28.9	7.2	77.0	501	321	250	218	7.4	7.0	1.0	0.68	0.3	42.4	70.7	4.9	3.2	48.1	23.6	0.007	ND	0.002	0.86	ND	ND	0.8
	MWb	Black	Unpleasent	15.6	6.9	57.0	960	124	470	151	7.6	8.5	1.1	0.68	0.7	48.1	80.4	5.9	18.2	72.0	21.6	0.026	0.098	0.005	2.765	ND	ND	0.9
6	Khanpur																											
	MWa	Black	Unpleasent	23	7.2	50.0	500	319	460	199	79.0	48.0	1.1	0.71	ND	6.3	9.0	5.0	3.5	75.0	24.5	0.007	ND	0.002	0.87	ND	ND	0.7
	MWb	Black	Unpleasent	20.1	7.0	51.0	510	340	470	160	80.0	44.0	1.1	0.75	ND	7.6	10.1	5.1	3.6	76.0	25.0	0.007	ND	0.002	0.9	ND	ND	0.7
7	Gurukul Narsan																											
	MWa	Black	Unpleasent	29.1	7.2	49.0	520	350	480	171	60.0	22.0	1.0	0.61	ND	7.5	10.2	4.3	2.2	69.0	20.0	0.002	ND	ND	0.65	ND	ND	0.6
	MWb	Black	Unpleasent	20	7.6	55.0	580	410	490	125	62.0	70.0	1.0	0.62	ND	8.3	12.1	4.5	2.1	70.0	21.0	0.003	ND	ND	0.72	ND	ND	0.7
8	Manglore																											
	MWa	Black	Unpleasent	31	7.3	82.5	1794	1148	580	400	14.0	60.5	3.1	0.5	ND	42.4	70.1	16.3	10.2	162.0	3.6	0.012	0.082	0.064	12.2	ND	ND	1.8
	MWb	Black	Unpleasent	18.5	7.1	76.0	1432	1290	582	210	202.0	30.1	2.0	0.1	ND	49.1	81.8	16.3	68.6	136.0	4.2	ND	0.092	0.014	1.191	ND	ND	2
9	Jhabrera																											
	MWa	Black	Unpleasent	30.2	7.3	41.6	1890	1209	530	200	21.0	15.0	2.8	0.22	ND	48.3	80.9	18.5	9.1	67.0	2.9	0.014	0.008	0.035	1.884	ND	ND	3.1
	MWb	Black	Unpleasent	15.6	7.1	173.0	2350	1506	536	260	66.0	16.0	1.4	0.81	ND	49.0	81.3	15.5	68.0	80.0	27.3	0.003	0.083	0.028	0.985	ND	ND	2.1
10	Iqbalpur																											
	MWa	Black	Unpleasent	29.3	7.4	80.2	740	610	300	198	11.9	40.0	1.8	0.4	ND	36.0	60.0	11.5	3.4	78.0	8.3	0.007	ND	0.013	1.098	ND	ND	1.8
	MWb	Black	Unpleasent	19.7	7.1	50.0	924	591	578	260	46.0	8.1	1.1	0.45	ND	38.8	69.5	8.1	8.0	128.0	9.0	ND	0.07	0.077	1.333	ND	ND	1
	IWa	Brown	Unpleasent	26	7.7	15.0	810	580	520	230	49.0	29.0	1.0	0.65	ND	18.8	28.0	12.0	3.4	80.2	20.1	0.005	ND	ND	1.101	ND	ND	1.7
	IWb	Brown	Unpleasent	29	6.7	40.0	920	810	521	140	49.0	29.0	1.0	0.65	ND	18.5	29.0	13.0	3.4	61.0	21.0	0.004	ND	ND	1.15	ND	ND	2
11	Bhagvanpur																											
	MWa	Black	Unpleasent	34.9	7.4	110.0	695	442	290	200	10.9	16.5	1.6	1.6	1.6	42.4	70.8	9.5	1.7	59.4	15.0	0.002	ND	0.018	3.786	ND	ND	1.5
	MWb	Black	Unpleasent	19.4	7.2	70.0	1120	710	440	220	66.0	20.5	1.9	0.51	ND	49.4	80.5	12.2	15.5	76.0	17.5	ND	0.05	0.017	2.245	ND	ND	1.8

MW : Municipal Waste , IW : Industrial Waste , a: Pre Monsoon Samples and b: Post Monsoon Samples , EC: Electrical Conductivity, TDS :Total Dissolved Solids, DO: Dissolved Oxygen , BOD: Biological Oxygen Demand , COD: Chemical Oxygen Demand , SAR: Sodium Adsorption Ratio and ND: Not Detected

the exception of the ground water of Iqbalpur (100 feet) and Jhabreda (50 feet). The wastewater samples were found with unpleasant taste. There was no marked effect on the odor and taste of the surface, ground and waste water in the post monsoon season.

6.3. Temperature

The variation of the temperature of surface, ground and waste waters was found from 21.4 to 28.0, 16.1 to 30.8 and 22.7 to 34.9.0 °C respectively in the pre-monsoon season while in case of the post-monsoon seasons it varied from 14.0 to 20.0, 14.1 to 28.8 and 15.6 to 20.1 °C respectively. The variation in temperature may be due to the change in climate of the pre- and the post-monsoon seasons.

6.4. pH

The pH ranged from to 7.80 to 8.08, 7.0 to 8.5 and 7.00 to 8.15 in surface, ground and waste water samples respectively in the pre-monsoon season while it varied from 7.00 to 8.25, 6.4 to 8.1 and 6.7 to 7.6 in surface, ground and waste waters respectively in the post-monsoon season. The values of the pH were satisfactory for drinking purpose (ISI, 1991).

6.5. Turbidity

The turbidity of the samples ranged from 40.0 to 106.0, 1.0 to 26.2 and 8.1 to 173 NTU in surface, ground and waste waters in the pre-monsoon season while it varied from 4.0 to 110.0, 1.0 to 53.0 and 7.0 to 173.0 NTU respectively in the post-monsoon season. The turbidity of the surface and ground water samples were satisfactory (ISI, 1991) except in case of canal water at Hardwar, Bahadrabad, Kaliyar and Roorkee (the pre-monsoon season) and ground water at Kaliyar, Laksar and Iqbalpur. The turbidity of waste water

ranged from 8.1 to 110.0 NTU and 7.0 to 173.0 NTU in the pre- and the post-monsoon season respectively.

6.6. Conductivity

The conductivity varied from 128.0 to 408.0, 210.0 to 1361.0 and 500.0 to 1890.0 μS/cm in surface, ground and waste waters respectively in the pre-monsoon season while it ranged from 131.0 to 440.0, 211.0 to 1729 and 510 to 2350 μS/cm in the post-monsoon season. The conductivity is due to the presence of dissolved ionic solids.

6.7. Total Dissolved Solids (TDS)

The TDS ranged from 82.0 to 260.0, 130.0 to 855.0 and 319.0 to 1209.0 mg/L in surface, ground and waste waters respectively in the pre-monsoon season while it varied from 120.0 to 280.0, 131.0 to 850.0 and 204.0 to 1506.0 mg/L in surface, ground and waste waters respectively in the post-monsoon season.

6.8. Hardness

The hardness was found to be 70.0 to 190.0 mg/L in surface, 100.0 to 550.0 mg/L in ground and 250.0 to 580.0 mg/L in waste waters respectively in the pre-monsoon season while it ranged from 96.0 to 191.0, 110.0 to 583.0 and 290.0 to 582.0 mg/L in surface, ground and waste waters respectively in the post-monsoon season. These values of hardness indicate the presence of carbonates, bicarbonates, sulphates and chlorides of calcium and magnesium. A comparison of these values with the standard values (ISI, 1991) indicates that the ground water is hard at some of the places.

6.9. Alkalinity

The alkalinity ranged from 57.0 to 225.0, 132.0 to 458.0 and 140.0 to 400.0 mg/L in surface, ground and waste waters respectively in the pre-monsoon season while it varied from 30.0 to 220.0, 110.0 to 380.0 and 130.0 to 290.0 mg/L in surface, ground and waste waters respectively in the post-monsoon season. The alkalinity may be due the presence of bicarbonates, carbonates and hydroxides.

6.10. Chloride

The values of chloride in surface, ground and waste waters were found in the range of 5.0 to 78.1, 4.7 to 151.0 and 7.4 to 116.4 mg/L respectively in the pre-monsoon season while these values varied from 4.0 to 75.3, 4.4 to 150.9 and 6.5 to 202.0 mg/L in the post-monsoon season. The comparison of the chloride values with the standard (ISI, 1991) indicates that the chloride concentration is satisfactory in surface and ground waters. However, the high values of chloride in the Ganga at Hardwar may be because of some industrial effluents joining the river at that particular time.

6.11. Sulphate

The values of sulphate ranged from 0.7 to 8.0, 5.1 to 74.0 and 7.0 to 60.5 mg/L in surface, ground and waste waters respectively in the pre-monsoon season while these values varied from 2.6 to 29.0, 3.5 to 50.0 and 8.5 to 73.0 mg/L respectively in the post-monsoon season. The maximum permissible value of sulphate is 200 mg/L (ISI, 1991) and, therefore, water is suitable for drinking purpose by the sulphate point of view.

6.12. Nitrate

The value of nitrate varied from 0.7 to 8.0, 0.1 to 20.1 and 1.0 to 5.1 mg/L in surface, ground and waste waters respectively in the pre-monsoon season while these values ranged from 0.4 to 6.2, 0.4 to 20.0 and 0.95 to 4.9 mg/L respectively in the post-monsoon season. The value of the nitrate is satisfactory in all the three category of waters as per Indian standards (ISI, 1991).

6.13. Phosphate

The values of phosphate were found in the range of 0.1 to 0.5, 0.005 to 0.230 and 0.1 to 0.7 mg/L in surface, ground and waste waters respectively in the pre-monsoon season while these values varied from 0.02 to 0.60, 0.02 to 0.30 and 0.91 to 0.91 mg/L respectively in the post-monsoon season.

6.14. Dissolved oxygen (DO)

The values of dissolved oxygen ranged from 7.2 to 8.9, 0.9 to 3.0 and 0.3 to 1.9 mg/L in surface, ground and waste waters respectively in the pre-monsoon season while these values varied from 6.2 to 10.5, 1.0 to 2.1 and 0.7 to 3.4 respectively in the post-monsoon season. It is also clear from Table 6 that dissolved oxygen has not been detected in most of the wastewater samples. It may be due to the decomposition of organic biodegradable matter by microbes in wastewater which consume DO for this degradation. The low value of DO (surfacewater) at Roorkee may be due to the presence of biodegradable organic matter at that particular time.

6.15. Biological Oxygen Demand (BOD)

The values of BOD varied from 6.3 to 7.7, 1.2 to 10.3 and 6.3 to 55.9 mg/L in surface, ground and waste waters respectively in the pre-monsoon season while these values in the post-monsoon season were found to be in the range of 5.3 to 8.8, 1.2 to 10.1 and 7.3 to 61.8 mg/L respectively. The high values of BOD in wastewater and some of the surface and ground waters indicate the presence of biodegradable organic contamination. It has also been observed that the values of BOD were found to be higher in the upper (50 feet) ground water in comparison to the deeper ground water (100 and more than 100 feet). It is also interesting to observe that he values of BOD were found to be higher in the post-monsoon season. It may be due to the addition of biodegradable organic matters by rain.

6.16. Chemical Oxygen Demand (COD)

The values of COD were found to be 9.0 to 11.0, 3.5 to 20.0 and 5.0 93.2 mg/L in surface, ground and waste waters respectively in the pre-monsoon season while these values varied from 7.9 to 12.5, 0.1 to 24.3 and 10.1 to 103.5 mg/L respectively in the post-monsoon season. The high values of COD in wastewaters indicate the high polluted nature of the wastewaters. It has been observed that the COD values were higher in the upper zone (50 feet) of groundwater. It is also clear from Table 4, 5 and 6 that the values of COD increased in the post-monsoon seasons in surface, ground and waste water samples. It may be due to the addition of extra organic matter into surface, ground and waste waters in rainy season.

6.17. Sodium

The values of sodium ranged from 8.0 to 55.0, 2.5 to 47.0 and 4.5 to 96.0 mg/L in surface, ground and waste waters respectively in the pre-monsoon season while the values of sodium were found to be in the range of 33.4 to 55.0, 2.5 tp 62.8 and 4.5 to 96.0 mg/L respectively in the post-monsoon season. The high values in post-monsoon season may be due to the addition of sodium by rain.

6.18. Potassium

The values of potassium were in the range of 2.6 to 6.0, 0.4 to 18.6 and 1.0 to 2.2 mg/L in surface, ground and waste waters respectively in the pre-monsoon season while these values varied from 4.0 to 5.9, 0.4 to 32.1 and 1.0 to 68.6 mg/L in the post-monsoon season. The variation of potassium values may be due to the effect of monsoon.

6.19. Calcium

The values of calcium were found to be in the range of 21.7 to 53.0, 13.6 to 190.0 and 48.1 to 162.0 in surface, ground and waste waters respectively in the pre-monsoon season while these values in the post-monsoon season were in the range of 25.7 to 72.0, 18.9 to 180.2 and 70.0 to 136.0 mg/L respectively. It is clear from these values that water is hard at most of the places as per ISI standards.

6.20. Magnesium

The values of magnesium varied from 3.4 to 14.0, 8.6 to 54.7 and 1.9 to 24.5 mg/L in surface, ground and waste waters respectively in the pre-monsoon season while these values ranged from 4.9 to 7.8, 7.0 to 60.4 and 1.8 to 27.3 mg/L respectively in the post-monsoon season.

6.21. Cadmium

The values of cadmium ranged from 0.006 to 0.001, 0.002 to 0.109 and 0.002 to 0.100 mg/L in surface, ground and waste waters respectively in the pre-monsoon season while these values ranged from 0.001 to 0.012, 0.001 to 0.104 and 0.003 to 0.110 mg/L respectively in the post-monsoon season. Besides, cadmium has not been detected at some of the sampling points. The variation in the values of post-monsoon may be due the dilution by monsoon.

6.22. Lead

The values of lead were found in the range of 0.027 to 0.987, 0.030 to 0.200 and 0.008 to 0.564 in surface, ground and waste waters respectively in the pre-monsoon season while these values varied from 0.047 to 0.079, 0.015 to 0.410 and 0.096 to 0.119 respectively in the post-monsoon season. In addition to this, lead has not been detected at some of the sampling points.

6.23. Copper

The values of copper were found from 0.008 to 0.062, 0.001 to 0.080 and 0.002 to 0.084 mg/L in surface, ground and waste waters respectively in the pre-monsoon seasons while these values were in the range of 0.002 to 0.062, 0.001 to 0.102 and 0.002 to 0.077 mg/L respectively in the post-monsoon season respectively. In addition to these results, copper has not been detected at some of the sampling points.

6.24. Iron

The values of iron were found in the range of 0.677 to 6.120, 0.005 to 12.500 and 0.359 to 12.200 mg/L in surface, ground and waste waters respectively in the pre-monsoon seasons while these values were in the range of 0.285 to 1.450, 0.003 to 4.989 and 0.253 to 4.452 mg/L respectively in the post-monsoon season respectively.

6.25. Cobalt

Cobalt has not been detected in most of the water samples. However, the values of cobalt in some of the cases varied from 0.001 to 0.005 mg/L.

6.26. Chromium

Chromium was absent in all water samples analyzed.

6.27 Sodium Adsorption Ratio (SAR)

The value of SAR is very important in agricultural and forestry activities as the values of sodium adsorption ratio are used to identify the suitability of water for irrigation purposes. The value of SAR is calculated by the following formula (Hem, 1970).

$$SAR = \frac{Na}{\sqrt{(Ca+Mg)/2}}$$

The U.S. Salinity Laboratory, Department of Agriculture, U.S.A. has classified water, for irrigation purposes, into four groups as given below.

SAR Value	Water Class
< 10	Excellent
10 - 18	Good
18 26	Fair
> 26	Poor

The values calculated for SAR in surface, ground and waste waters were ranged from 2.2 to 9.5, 0.4 to 8.0 and 0.6 to 12.1 respectively in the pre-monsoon season while in the post-monsoon season these varied from 5.3 to 9.5, 0.4 to 10.1 and 0.3 to 6.5 respectively. It is clear from the values of SAR given in Table 4, 5 and 6 that the surface, ground and waste waters are of excellent and good classes for irrigation purposes. The ionic balance was calculated and it was found that the values of the ionic balance were below 10% indicating the satisfactory analysis of the water samples.

7. SOURCES OF WATER POLLUTION

The detail results of water analysis of district Hardwar are given in Table 4, 5 and 6 for surface, ground and waste waters respectively. It is clear from these Tables that the quality of surface and ground waters is safe and good and agrees with the Indian standards (ISI, 1991) standards. However, the quality of surface and ground water at some of the places is not good. The results of the wastewater indicate that the wastewater is highly polluted and contaminating the water resources in district Hardwar. The maximum possible sources of water contamination, present in district Hardwar, are discussed below.

7.1. Municipal Activities

7.2. Industrial Activities

7.3. Agricultural Activities

7.4. Land Disposal of Solid Wastes

7.5. Land Disposal of Sewage

7.6. Geochemical Reactions

7.1. Municipal Activities

The municipal and domestic activities are producing a large quantity of effluents and solid wastes. The effluents and the solid wastes are highly polluted due to the presence of a variety of chemicals, faeces and other refusees. The microbial population is also very high in these wastes. It is clear from Table 6 that the wastewater is highly polluted and in this way polluting the surface and ground waters. It has been observed that the municipal waste mixed directly into the surfacewater while it leach into groundwater slowly. It has also been observed that the degree of pollution by the waste is directly proportional to the size and load of the place.

7.2. Industrial Activities

The district Hardwar does not have a nucleus of industries. However, the Sugar Mill at Iqbalpur is polluting the groundwater of the nearby area. The small scale industries at Hardwar are also contributing the surface and ground waters pollution. The effluents of these industries contain a variety of pollutants including organics and inorganics. The effluents either get mixed directly into surfacewater or leached into groundwater. It has also been observed that the degree of contamination is high in the upper zone of groundwater.

7.3. Agricultural Activities

The agricultural activities are also playing an important role in contaminating the surface and ground waters. The presence of sulphate, nitrate, phosphate etc. in the surface and ground waters may be due to the agricultural activities. The periodical irrigation of the agricultural land resulted into the leaching of the pollutants into groundwater. The sources of these pollutants are fertilizers, compost and pesticides used in agricultural lands.

7.4. Land Disposal of Solid Wastes

Some times solid wastes are disposed on the land where they decomposes and produces a leachate that can contaminate surface and ground waters. The landfills ranges from unmanaged dumps to carefully designed and operated 'Sanitary' landfills. The amount of leachate produced in the landfill depends on amount and distribution of rainfall, hydraulic conductivity of cover soil, evaporation from cover soil and freezing and thawing. The chemical composition of leachate depends on the nature of the refuse, on the leaching rate and on the age of the fill. The landfills are the point source pollution and the leachate movement in the soil forms a narrow band or plume, unless of course, the groundwater is stagnant.

7.5. Land Disposal of Sewage

The sewage pollution occurs from septic tank, cesspools and a device where the sewage is applied to land for crop irrigation, groundwater recharge or disposal. The pollution through leakage from sewers, sewage lagoon and dumps (in which sewage is discharged) are also occurred.

7.6. Geochemical Reactions

The geochemical reactions taking place in the earth are playing an important role in contaminating the ground water. The rate of these geochemical reactions vary from season to seasons as the temperature varies from season to season. The presence of traces of heavy toxic metal ions such as lead, copper, iron, cobalt, chromium etc. may be due to these geochemical reactions.

8. CONCLUSION

The detail results obtained from the analysis of surface, ground and waste water samples are given in Table 4, 5 and 6 respectively. It is clear from these Tables that the quality of surface and ground waters is quite good and safe as per the Indian standards. However, the quality of surface water at some of the places is not good. It has also been observed that the quality of ground water upto 50 feet is not good and contain various inorganics and organics while the quality of waters at higher depth is good and safe. It may be due to the leaching of inorgainces and organics in the aquifers at about 50 feet while the leaching of these contaminant upto 100 feet or more has not been observed but it may be possible after a long period of time. The results obtained from wastewater samples indicate that the wastewater is highly polluted. It is also clear from these results that the municipal wastewater is more polluted than the industrial wastewater in district Hardwar. The possible sources of the water pollution in district Hardwar are municipal, industrial and agricultural activities, land disposal of solid wastes, sewage disposal on land, deep well disposal of liquid wastes, petroleum and other oils leakages and geochemical reactions. Water pollution due to industrial effluent is very poor in Hardwar as the district contains a very few industries. However, the groundwater around the Iqbalpur Sugar Mill is not good as it has been polluted by this Mill itself. The effect of the monsoon on the water quality has been studied and it was found that there was no marked effect of the rain on the water quality of the district. However, the dilution effect on the surface, ground and waste waters quality has been observe. In some of the cases, the value of COD has increased in post-monsoon seasons. It may be due to the addition of certain chemical in water resources in post-monsoon season. The values of SAR calculated indicate that the surface, ground and waste waters are of excellent and good classes for irrigation purposes.

Keeping all these results and discussion into consideration, it may be concluded that the water quality of the district Hardwar is good and safe but it may deteorate after a period of time due the continuous addition of undesired chemicals in water resources. Therefore, the municipal wastewater should also be treated properly before its discharge either into river or on land. The effluent specially of Iqbalpur Sugar Mill should be treated properly prior to its disposal on land. In addition to this, the practice of digging the faeces and wastes into ground should be avoided. The land disposal of solid wastes and sewage should be avoided as much as possible. The farmers should use the newly developed low toxic pesticides in crops.

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