Consultancy Project Report

Pilot Study on Ground Water Pollution in Hindon-Kali-Krishni River Catchment in Western Uttar Pradesh

Submitted to:

Water & Sanitation Support Organization (WSSO)
State Water and Sanitation Mission (SWSM)
Department of Rural Development
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PREFACE

Ground water forms the major source of water supply for drinking purposes in most part of the country. For proper utilization of water for various purposes, understanding of geo-chemical controls and study of the extent of ground water contamination are of prime importance. The quality of ground water is particularly important to humans when the water is used for drinking water supply. The quality of ground water varies from place to place along with the depth of water table. It also varies with seasonal changes and is primarily governed by the extent and composition of dissolved solids present in it.

There has been heavy dependence on ground water in recent decades due to growth in agriculture, population and industries in many parts of our country. The State of Uttar Pradesh has made significant achievements in the field of providing drinking water in rural areas of Uttar Pradesh. More than 2.1 million hand pumps and 8,000 piped water supply schemes are catering to the need of slightly over 2.6 lakh habitations from 52,000 Gram Panchayats. However, systematic planning for sustainable rural drinking water supply has emerged as one of the major issues. To address the new challenges, Govt. of India has initiated some steps and during past few months there has been rapid institutional restructuring in the water sector. Water & Sanitation Support Organization (WSSO) is the new institution which has been entrusted to provide oversight support to the implementing partners (IPs) namely U.P. Jal Nigam, U.P. Agro and implementation wing of State Water and Sanitation Mission (SWSM).

In order to ensure sustainable rural drinking water supply in Hindon-Kali-Krishni catchment in Western Uttar Pradesh, Water & Sanitation Support Organization (WSSO), State Water and Sanitation Mission (SWSM), Department of Rural Development, Govt. of Uttar Pradesh, Lucknow entrusted consultancy study on "Pilot Study on Ground Water Pollution in Hindon-Kali-Krishni River Catchment in Western Uttar Pradesh" to the National Institute of Hydrology (NIH), Roorkee with the objectives to study ground water/drinking water quality in villages located in the buffer zone of 2 km on the banks of Rivers Hindon, Kali and Krishni in 7 Districts of Western Uttar Pradesh and to analyze water quality data and make suitable recommendations for development of mitigation strategy for providing safe drinking water on sustainable basis to the affected people.

The project report has been prepared by Dr. C. K. Jain, Sc. 'F' & Head, Dr. M. K. Sharma, Sc. 'C' and Dr. Rajesh Sigh, Sc. 'B' of Environmental Hydrology Division, National Institute of Hydrology, Roorkee. I hope that the report will be of immense use to the planners, scientists and engineers concerned with the management and protection of ground water quality in Hindon-Kali-Krishni river catchment in Western Uttar Pradesh.

Raj Deva Singh

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

1. Total sixteen river water samples from River Hindon, Kali and Krishni were collected with about 5-6 samples from the length of each river running in the project area along with their GPS coordinates during March 2013 and analyzed for various physico-chemical parameters, trace elements and pesticides.
2. Ground water quality from various drinking water sources located in different habitations in the buffer zone of 2 km on the banks of Rivers Hindon, Kali and Krishni with about 2-3 samples from each village, one sample from each strata, covering 75 villages from 7 Districts of Western Uttar Pradesh (Saharanpur, Muzaffarnagar, Shamli, Meerut, Baghpat, Ghaziabad and Gautambudh Nagar) has been examined to see the suitability of ground water for drinking purpose.
3. Two hundred two representative ground water samples from various drinking water sources (Private Hand Pumps, IM II Hand Pumps and Tube Wells / Bore Wells) were collected during March 2013 and analyzed for various physico-chemical, bacteriological and trace elements. The hydro-chemical, bacteriological and trace element data has been analyzed with reference to Drinking Water Specifications (BIS, 2012). Water Quality Index (WQI) has been developed for different drinking water sources.
4. The quality of the ground water varies from place to place with the depth of water table. The ground water from shallow aquifers (Provate Hand Pumps) are more prone to nitrate contamination, which may be attributed to disposal of municipal wastes and agricultural activities in the region.
5. The bacteriological analysis of the samples indicates some sign of bacterial contamination at few locations. Inadequate maintenance of hand pump, improper sanitation and unhygienic conditions around the structure may be responsible for bacterial contamination at these locations.
6. The presence of trace elements has been recorded at many location and the water quality standards have been violated for various metals.
7. The analysis of pesticides in ground water indicated the presence of some chlorinated pesticides (γ-BHC and Methoxychlor) and is a cause of serious concern. The presence of γ-BHC and/or methoxychlor in ground water may be attributed due to their use in agricultural activities and for vector control programmes. The pesticide applied on surface might have leached through soil strata under the influence of hydraulic gradient and become source of contamination in ground water.
8. The water quality data has been analyzed and suitable recommendations have been made for development of mitigation strategy for providing safe drinking water on sustainable basis to the affected people.

1.0 INTRODUCTION

Ground water forms the major source of water supply for drinking purposes in most part of the country. For proper utilization of water for various purposes, understanding of geo-chemical controls and study of the extent of ground water contamination are of prime importance. The quality of ground water is particularly important to humans when the water is used for drinking water supply. The quality of ground water varies from place to place along with the depth of water table. It also varies with seasonal changes and is primarily governed by the extent and composition of dissolved solids present in it.

In recent years, an increasing threat to ground water quality due to human activities has become of great importance. The adverse effects on ground water quality are the results of man's activity at ground surface, unintentionally by agriculture, domestic and industrial effluents, unexpectedly by sub-surface or surface disposal of sewage and industrial wastes.

A vast majority of ground water quality problems are caused by contamination, over-exploitation, or combination of the two. Most ground water quality problems are difficult to detect and hard to resolve. The solutions are usually very expensive, time consuming and not always effective. Ground water quality is slowly but surely declining everywhere. Ground water pollution is intrinsically difficult to detect, since problem may well be concealed below the surface and monitoring is costly, time consuming and somewhat hit-or-miss by nature.

The wide range of contamination sources is one of the many factors contributing to the complexity of ground water assessment. It is important to know the geochemistry of the chemical-soil-groundwater interactions in order to assess the fate and impact of pollutant discharged on to the ground. Pollutants move through several different hydrologic zones as they migrate through the soil to the water table. The serious implications of this problem necessitate an integrated approach in explicit terms to undertake ground water pollution monitoring and abatement programmes.

The intensive use of natural resources and the large production of wastes in modern society often pose a threat to ground water quality and have already resulted in many incidents of ground water contamination. Pollutants are being added to the ground water system through human activities and natural processes. Solid waste from industrial units is being dumped near the factories, which is subjected to reaction with percolating rain water and reaches the ground water level. The percolating water picks up a large amount of dissolved constituents and reaches the aquifer system and contaminates the ground water. The problem of ground water pollution in several parts of the country has become so acute that unless urgent steps for detailed identification and abatement are taken, extensive ground water resources may be damaged.

The quality of ground water depends on a large number of individual hydrological, physical, chemical and biological factors. Generally higher proportions of dissolved constituents are found in ground water than in surface water because of greater interaction of ground water with various materials in geologic strata. The water used for drinking purpose should be free from any toxic elements, living and nonliving organism and excessive amount of minerals that may be hazardous to health. Some of the heavy metals are extremely essential to humans, for example, cobalt, copper, etc., but large quantities of them may cause physiological disorders.

The contamination of ground water by heavy metals and pesticides has also assumed great significance during recent years due to their toxicity and accumulative behaviour. These elements, contrary to most pollutants, are not biodegradable and undergo a global eco-biological cycle in which natural waters are the main pathways. The determination of the concentration levels of heavy metals and pesticides in these waters, as well as the elucidation of the chemical forms in which they appear is a prime target in environmental research today.

There has been heavy dependence on ground water in recent decades due to growth in agriculture, population and industries in many parts of our country. The State of Uttar Pradesh has made significant achievements in the field of providing drinking water in rural areas of Uttar Pradesh. More than 2.1 million hand pumps and 8,000 piped water supply schemes are catering to the need of slightly over 2.6 lakh habitations from 52,000 Gram Panchayats. However, systematic planning for sustainable rural drinking water supply has emerged as one of the major issues. To address the new challenges, Govt. of India has initiated some steps and during past few months there has been rapid institutional restructuring in the water sector. Water & Sanitation Support Organization (WSSO) is the new institution which has been entrusted to provide oversight support to the implementing partners (IPs) namely U.P. Jal Nigam, U.P. Agro and implementation wing of State Water and Sanitation Mission (SWSM).

In order to ensure sustainable rural drinking water supply in Hindon-Kali-Krishni catchment in Western Uttar Pradesh, Water & Sanitation Support Organization (WSSO), State Water and Sanitation Mission (SWSM), Department of Rural Development, Govt. of Uttar Pradesh, Lucknow entrusted consultancy study on “Pilot Study on Ground Water Pollution in Hindon-Kali-Krishni River Catchment in Western Uttar Pradesh” to the National Institute of Hydrology (NIH), Roorkee with the following objectives:

i) To study ground water/drinking water quality in villages located in the buffer zone of 2 km on the banks of Rivers Hindon, Kali and Krishni in 7 Districts of Western Uttar Pradesh
ii) To analyze water quality data and make suitable recommendations for development of mitigation strategy for providing safe drinking water on sustainable basis to the affected people.

2.0 HINDON-KALI-KRISHNI RIVER CATCHMENT

The River Hindon is among one of the important rivers in Western Uttar Pradesh (India) having a basin area of about 7000 km^2. The catchment area is a part of Indo-gangetic Plains, composed of Pleistocene and subrecent alluvium and lies between latitude 28^o30' to 30^o15' N and longitude 77^o20' to 77^o50' E. The river originates from Upper Shivaliks (Lower Himalayas) and flows through five major districts, viz., Saharanpur, Muzaffarnagar, Meerut, Ghaziabad and Gautambudh Nagar in Western Uttar Pradesh and covers a distance of about 200 km before joining the River Yamuna downstream of Delhi.

The two important tributaries of River Hindon are River Kali and River Krishni. The River Kali originates near Saharanpur District in Western Uttar Pradesh and traverses a distance of 125 km before joining the River Hindon on its left bank near the Village of Atali. The River Krishni originates in District Saharanpur and traverses a distance of about 150 km before joining the River Hindon on its right bank at Village Barnawa in Baghpat District. The River Krishni passes through three major industrially and agriculturally advanced districts of Western Uttar Pradesh, viz., Saharanpur, Shamli and Baghpat.

2.1 Physiography and Drainage

Physiographically the area is generally flat except Shivalik hills in the north and north east. The area is devoid of relief features of any prominence except deep gorges cut by nalas and rivers flowing through the area. The River Hindon and its tributaries generally flow from north to south. These rivers carry base flow from ground water storage during the non-monsoon season. The important tributaries include River Kali and River Krishni. Apart from these rivers, the Upper Ganga Canal also drain the area.

2.2 Geology

The area under study is a part of Indo-gangetic plains, which is mainly composed of pleistocene and subrecent alluvial sediments transported and deposited by river action from the Himalayan region. Lithologically, sediments consist of clay, silt and fine to coarse sand. The deposits of sandy horizons of varying thickness are the main source of ground water in the area. The soils are very fertile for growing wheat, sugar cane and vegetables. However, along the sandy river course, fruit orchards are also common.

2.3 Land Use Pattern

The major land use in the basin is agriculture and there is no effective forest cover. The basin is densely populated because of the rapid industrialization and agricultural growth during last few decades. Several industries related to paper, sugar, distillery and many small scale cottage industries related to electroplating, paper board, food processing, milk products, chemicals and rubber etc., located in the western part of Uttar Pradesh, release their waste effluents into the river through various open drains. Due to the continuous pollution load, the river's environmental matrix has become very complex.

2.4 Climate

The climate of the region is moderate subtropical monsoon type. It has a cool dry winter season from October to March, a hot dry summer season from April to June and a warm rainy season from July to September. The average annual rainfall is about 1000 mm, major part of which is received during the monsoon period (June to September). The daily maximum rainfall was observed to be 122 mm in the basin. The daily maximum temperature varies from 10 to 43 ºC and minimum temperature varies from 4.6 to 29.2 ºC.

2.5 Sources of Pollution

2.5.1 River Hindon

The main sources of pollution in River Hindon include municipal wastes from Saharanpur, Muzaffarnagar and Ghaziabad urban areas and industrial effluents of sugar, pulp and paper, distilleries and other miscellaneous industries through tributaries namely River Kali and Krishni, as well as direct outfalls. In summer months the river is completely dry from its origin upto Saharanpur town. The waste water and effluents of Nagdev Nala and Star Paper Mill at Saharanpur generate the flow of water in the river. The municipal wastewater generated from the Saharanpur City is discharged to the Hindon River through Dhamola Nala. The municipal wastewater from Budhana Town also join the river in this stretch. In Ghaziabad District, downstream of Karhera Village, major part of the river flow is diverted to Hindon cut canal at Mohan Nagar which meets River Yamuna upstream of Okhla barrage. Thereafter the River Hindon receives wastewater through Dhasana drain at Village Bisrakh in Gautambudh Nagar District. The Dhasana drain carries the wastewater of municipal as well as industrial establishments. River Hindon flows further downstream and joins River Yamuna at village Tilwara.

2.5.2 River Kali

The River Kali is subjected to varying degree of pollution caused by numerous untreated outfalls of municipal and industrial effluents. The main sources which create pollution in the River Kali include municipal wastes of Deoband and Muzaffarnagar City, industrial waste from a variety of industries (such as steel, rubber, ceramic, chemicals, plastic, dairy, pulp and paper and laundries) and Mansurpur Sugar Mill and Distillery waste. The waste effluents stagnate in the River Kali for a long time, because of which the biological action starts and obnoxious condition soon develop in the region. This septic condition results in the production of hydrogen sulphide gas imparting black colour to the river water.

2.5.2 River Krishni

The river passes through three major industrially and agriculturally advanced districts of Western Uttar Pradesh, viz., Saharanpur, Shamli and Baghpat. It receives domestic and industrial effluents (such as sugar, distillery, card board, food products etc.) throughout its length of about 150 km. The waste effluents stagnate in the river during lean period, because of which the biological action starts and obnoxious condition soon develop in the region.

3.0 EXPERIMENTAL METHODOLOGY

3.1 Sampling and Preservation

Sixteen river water samples from River Hindon, Kali and Krishni were collected in polyethylene bottles with about five samples from the length of each river running in the project area along with their GPS coordinates during March 2013 and preserved by adding an appropriate reagent (Jain and Bhatia, 1988; APHA, 1992). The description of the sampling locations along with their GPS coordinates is given in Table 3.1.

Table 3.1 Description of River Water Sampling Locations

S.No.	Location	Sample ID	Lat	Long
River Hindon				
1.	Kapasa	HIN-1	29^{0}54'60" N	77^{0}35'43" E
2.	Tansipur	HIN-2	29^{0}49'34" N	77^{0}33'35" E
3.	Atali	HIN-3	29^{0}26'46" N	77^{0}30'14" E
4.	Barnawa	HIN-4	29^{0}06'52" N	77^{0}26'24" E
5.	Surana	HIN-5	28^{0}51'38" N	77^{0}24'59" E
River Kali				
6.	Banhera Khas	KL-1	29^{0}45'32" N	77^{0}42'11" E
7.	Palauli	KL-2	29^{0}41'43" N	77^{0}44'26" E
8.	Rohana Khurd	KL-3	29^{0}34'48" N	77^{0}42'40" E
9.	Sujru	KL-4	29^{0}25'58" N	77^{0}40'32" E
10.	Jeevana	KL-5	29^{0}19'13" N	77^{0}40'45" E
11.	Alam Girpur Faridpur	KL-6	29^{0}14'02" N	77^{0}33'57" E
River Krishni				
12.	Chandenamal	KR-1	29^{0}39'24" N	77^{0}27'25" E
13.	Raipur	KR-2	29^{0}33'55" N	77^{0}24'55" E
14.	Kudana	KR-3	29^{0}28'10" N	77^{0}21'41" E
15.	Sunna	KR-4	29^{0}19'30" N	77^{0}21'16" E
16	Barnawa	KR-5	29^{0}06'29" N	77^{0}25'17" E

Two hundred two representative ground water samples from different drinking water sources from villages located in different habitations in the buffer zone of 2 km on the banks of River Hindon, Kali and Krishni with about 2-3 samples from each village, one sample from each strata covering 75 villages from 7 districts of Uttar Pradesh – Saharanpur, Muzaffarnagar, Shamli, Meerut, Baghpat, Ghaziabad and Gautambudh Nagar were collected in polyethylene bottles along with their GPS coordinates during March 2013 and preserved by adding an appropriate reagent (Jain and Bhatia, 1988; APHA, 1992). The hand pumps were continuously pumped for at least 15 minutes prior to the sampling, to ensure that ground water to be sampled was representative of ground water aquifer. All the ground water samples were collected from the drinking water sources, which are being used extensively. The distribution of ground water samples collected from different districts is given in Table 3.2 while the description of ground water sampling locations along with their GPS coordinates are given in Table 3.3 to 3.9.

Table 3.2 Distribution of Ground Water Samples Collected from Different Districts

S.No.	District	No. of Villages Covered	No. of Sample Collected
1.	Saharanpur	28	68
2.	Muzaffarnagar	17	48
3.	Shamli	14	41
4.	Meerut	5	16
5.	Baghpat	6	15
6.	Ghaziabad	2	5
7.	Gautambudh Nagar	3	9
Total		**75**	**202**

Table 3.3 Description of Ground Water Sampling Locations in District Saharanpur

S.No.	Village	Source	Depth (m)	Sample ID	Lat	Long
1.	Sarda Heri	HP	31	SRE-1A	30^{0}03'24" N	77^{0}42'32" E
2.		IM II	37	SRE-1B	30^{0}03'24" N	77^{0}42'34" E
3.		TW	137	SRE-1C	30^{0}03'53" N	77^{0}42'46" E
4.	Ibrahimpur	HP	21	SRE-2A	30^{0}02'13" N	77^{0}43'59" E
5.		IM II	37	SRE-2B	30^{0}02'11" N	77^{0}43'52" E
6.	Pali	HP	46	SRE-3A	30^{0}00'34" N	77^{0}40'30" E
7.		IM II	37	SRE-3B	30^{0}00'34" N	77^{0}40'30" E
8.		TW	56	SRE-3C	30^{0}00'20" N	77^{0}40'14" E
9.	Gagalhedi	HP	18	SRE-4A	29^{0}57'54" N	77^{0}39'37" E
10.		IM II	37	SRE-4B	29^{0}58'29" N	77^{0}39'40" E
11.		TW	40	SRE-4C	29^{0}57'53" N	77^{0}37'22" E
12.	Khazoori Akbarpur	HP	20	SRE-5A	29^{0}56'55" N	77^{0}38'46" E
13.		IM II	37	SRE-5B	29^{0}56'55" N	77^{0}38'46" E
14.	Ghoghriki	HP	21	SRE-6A	29^{0}56'40" N	77^{0}35'40" E
15.		IM II	37	SRE-6B	29^{0}56'40" N	77^{0}35'40" E
16.	Paragpur	HP	21	SRE-7A	29^{0}55'49" N	77^{0}33'24" E
17.		IM II	37	SRE-7B	29^{0}55'49" N	77^{0}33'24" E
18.	Hasanpur banaswa	HP	26	SRE-8A	29^{0}55'40" N	77^{0}36'41" E
19.		IM II	37	SRE-8B	29^{0}55'40" N	77^{0}36'41" E
20.	Kapasa	HP	12	SRE-9A	29^{0}55'00" N	77^{0}36'34" E
21.		IM II	37	SRE-9B	29^{0}55'00" N	77^{0}36'34" E
22.	Tapri	HP	24	SRE-10A	29^{0}45'52" N	77^{0}32'56" E
23.		IM II	37	SRE-10B	29^{0}45'52" N	77^{0}32'56" E
24.		TW	55	SRE-10C	29^{0}45'53" N	77^{0}32'58" E
25.	Shekhpura kadim	HP	20	SRE-11A	29^{0}55'34" N	77^{0}34'19" E
26.		IM II	37	SRE-11B	29^{0}55'34" N	77^{0}34'19" E
27.	Lakhnour	HP	20	SRE-12A	29^{0}53'48" N	77^{0}36'02" E
28.		IM II	37	SRE-12B	29^{0}53'48" N	77^{0}36'02" E
29.		TW	46	SRE-12C	29^{0}53'10" N	77^{0}35'36" E

30.	Mubarakpur	HP	14	SRE-13A	29^{0}53'50" N	77^{0}34'20" E
31.		IM II	37	SRE-13B	29^{0}53'50" N	77^{0}34'20" E
32.	Nandi Must.	HP	24	SRE-14A	29^{0}52'48" N	77^{0}33'55" E
33.		IM II	37	SRE-14B	29^{0}52'48" N	77^{0}33'55" E
34.	Baleda Junardar	HP	24	SRE-15A	29^{0}52'47" N	77^{0}35'25" E
35.		IM II	37	SRE-15B	29^{0}52'47" N	77^{0}35'25" E
36.	Rasoolpur kheri	HP	21	SRE-16A	29^{0}52'13" N	77^{0}35'12" E
37.		IM II	37	SRE-16B	29^{0}52'13" N	77^{0}35'12" E
38.	Jainpur	HP	21	SRE-17A	29^{0}51'35" N	77^{0}34'42" E
39.		IM II	37	SRE-17B	29^{0}51'35" N	77^{0}34'42" E
40.	Sadhauli Hariya	HP	31	SRE-18A	29^{0}51'07" N	77^{0}33'22" E
41.		IM II	37	SRE-18B	29^{0}51'07" N	77^{0}33'22" E
42.	Tanshipur	HP	37	SRE-19A	29^{0}49'52" N	77^{0}34'12" E
43.		IM II	37	SRE-19B	29^{0}49'52" N	77^{0}34'12" E
44.		TW	56	SRE-19C	29^{0}49'44" N	77^{0}33'52" E
45.	Shitala Khera	HP	38	SRE-20A	29^{0}48'04" N	77^{0}35'13" E
46.		IM II	37	SRE-20B	29^{0}48'02" N	77^{0}35'15" E
47.		TW	46	SRE-20C	29^{0}47'55" N	77^{0}35'24" E
48.	Maheshpur	HP	37	SRE-21A	29^{0}42'23" N	77^{0}33'27" E
49.		IM II	37	SRE-21B	29^{0}42'23" N	77^{0}33'27" E
50.		TW	55	SRE-21C	29^{0}43'10" N	77^{0}33'33" E
51.	Mahmoodpur	HP	37	SRE-22A	29^{0}49'27" N	77^{0}43'54" E
52.		IM II	61	SRE-22B	29^{0}49'27" N	77^{0}43'54" E
53.	Bhataul	HP	24	SRE-23A	29^{0}48'06" N	77^{0}43'56" E
54.		IM II	37	SRE-23B	29^{0}48'06" N	77^{0}43'56" E
55.		BW	49	SRE-23B	29^{0}48'09" N	77^{0}43'45" E
56.	Banhera Khas	HP	14	SRE-24A	29^{0}45'42" N	77^{0}43'16" E
57.		IM II	37	SRE-24B	29^{0}45'42" N	77^{0}43'16" E
58.	Chandpur Kayasth	HP	20	SRE-25A	29^{0}43'04" N	77^{0}44'21" E
59.		IM II	37	SRE-25B	29^{0}43'04" N	77^{0}44'21" E
60.		BW	34	SRE-25C	29^{0}44'22" N	77^{0}44'22" E
61.	Palauli	HP	15	SRE-26A	29^{0}41'15" N	77^{0}44'23" E
62.		IM II	37	SRE-26B	29^{0}41'11" N	77^{0}44'22" E
63.	Sanpla Khatri	HP	7	SRE-27A	29^{0}39'43" N	77 43'23" E
64.		IM II	37	SRE-27B	29^{0}39'43" N	77^{0}43'23" E
65.		BW	34	SRE-27C	29^{0}39'57" N	77^{0}43'32" E
66.	Matauli	HP	15	SRE-28A	29^{0}37'35" N	77^{0}43'23" E
67.		IM II	37	SRE-28B	29^{0}37'35" N	77^{0}43'23" E
68.		BW	46	SRE-28C	29^{0}38'05" N	77^{0}44'32" E

HP – Private Hand Pump; IM II – India Mark II; TW – Tube Well; BW – Bore Well

Table 3.4 Description of Ground Water Sampling Locations in District Muzaffarnagar

S.No.	Village	Source	Depth (m)	Sample ID	Lat	Long
1.	Sujru	IM II	12	MZN-1B	29^{0}26'26" N	77^{0}41'41" E
2.		TW	30	MZN-1C	29^{0}26'22" N	77^{0}41'20" E
3.	Lachhera	HP	21	MZN-2A	29^{0}24'34" N	77^{0}39'49" E
4.		IM II	37	MZN-2B	29^{0}24'31" N	77^{0}39'52" E
5.		TW	38	MZN-2C	29^{0}24'29" N	77^{0}39'34" E

6.	Purbaliyan	HP	11	MZN-3A	29^{0}21'23" N	77^{0}39'22" E
7.		IM II	46	MZN-3B	29^{0}21'18" N	77^{0}40'10" E
8.		TW	67	MZN-3C	29^{0}21'19" N	77^{0}39'14" E
9.	Jeewna	HP	14	MZN-4A	29^{0}19'26" N	77^{0}39'60" E
10.		IM II	46	MZN-4B	29^{0}19'24" N	77^{0}40'00" E
11.		TW	24	MZN-4C	29^{0}19'19" N	77^{0}39'50" E
12.	Kilasa (Kitas)	HP	17	MZN-5A	29^{0}17'57" N	77^{0}36'34" E
13.		IM II	76	MZN-5B	29^{0}17'59" N	77^{0}36'35" E
14.		TW	61	MZN-5C	29^{0}18'09" N	77^{0}36'45" E
15.	Rohana Khurd	HP	14	MZN-6A	29^{0}35'27" N	77^{0}41'54" E
16.		IM II	37	MZN-6B	29^{0}35'28" N	77^{0}41'51" E
17.		TW	38	MZN-6C	29^{0}34'41" N	77^{0}41'23" E
18.	Didaheri	HP	18	MZN-7A	29^{0}31'09" N	77^{0}40'46" E
19.		IM II	34	MZN-7B	29^{0}31'11" N	77^{0}40'49" E
20.		TW	32	MZN-7C	29^{0}31'46" N	77^{0}41'19" E
21.	Kasoli	HP	24	MZN-8A	29^{0}36'10" N	77^{0}34'18" E
22.		IM II	55	MZN-8B	29^{0}36'10" N	77^{0}34'16" E
23.		TW	38	MZN-8C	29^{0}36'03" N	77^{0}34'24" E
24.	Nagla Rai	HP	6	MZN-9A	29^{0}33'13" N	77^{0}33'56" E
25.		IM II	38	MZN-9B	29^{0}33'12" N	77^{0}33'56" E
26.		TW	38	MZN-9C	29^{0}33'10" N	77^{0}33'56" E
27.	Ladwa	HP	9	MZN-10A	29^{0}30'25" N	77^{0}32'33" E
28.		IM II	49	MZN-10B	29^{0}30'24" N	77^{0}33'19" E
29.		TW	27	MZN-10C	29^{0}30'16" N	77^{0}32'47" E
30.	Atali	HP	14	MZN-11A	29^{0}26'35" N	77^{0}30'15" E
31.		IM II	24	MZN-11B	29^{0}26'33" N	77^{0}30'08" E
32.	Hadoli	HP	15	MZN-12A	29^{0}24'32" N	77^{0}30'41" E
33.		IM II	40	MZN-12B	29^{0}24'32" N	77^{0}30'40" E
34.		TW	46	MZN-12C	29^{0}24'42" N	77^{0}30'14" E
35.	Titawi	HP	17	MZN-13A	29^{0}28'15" N	77^{0}31'37" E
36.		IM II	46	MZN-13B	29^{0}28'16" N	77^{0}31'37" E
37.	Inchauli	HP	21	MZN-14A	29^{0}16'20" N	77^{0}36'27" E
38.		IM II	55	MZN-14B	29^{0}16'21" N	77^{0}36'28" E
39.		TW	21	MZN-14C	29^{0}16'21" N	77^{0}36'32" E
40.	Rampur	HP	18	MZN-15A	29^{0}16'53" N	77^{0}39'11" E
41.		IM II	46	MZN-15B	29^{0}16'53" N	77^{0}39'12" E
42.		TW	61	MZN-15C	29^{0}16'47" N	77^{0}39'10" E
43.	Chandsina	HP	17	MZN-16A	29^{0}17'31" N	77^{0}39'57" E
44.		IM II	46	MZN-16B	29^{0}17'33" N	77^{0}39'58" E
45.		TW	61	MZN-16C	29^{0}17'22" N	77^{0}39'50" E
46.	Budhana Khadar	HP	31	MZN-17A	29^{0}17'20" N	77^{0}28'22" E
47.		IM II	64	MZN-17B	29^{0}17'20" N	77^{0}28'23" E
48.		BW(PS)	104	MZN-17C	29^{0}17'23" N	77^{0}28'17" E

HP – Private Hand Pump; IM II – India Mark II; TW – Tube Well; BW(PS) – Bore Well Piped Water Supply

Table 3.5 Description of Ground Water Sampling Locations in District Shamli

S.No.	Village	Source	Depth (m)	Sample ID	Lat	Long
1.	Lisarh	HP	41	SML-1A	29^{0}21'39" N	77^{0}20'52" E
2.		IM II	73	SML-1B	29^{0}21'33" N	77^{0}20'48" E
3.		TW	73	SML-1C	29^{0}21'01" N	77^{0}21'01" E
4.	Bahawari	HP	70	SML-2A	29^{0}24'02" N	77^{0}22'36" E

5.		IM II	73	SML-2B	29^{0}24'01" N	77^{0}22'34" E
6.		TW	82	SML-2C	29^{0}24'08" N	77^{0}22'21" E
7.	Sunna	HP	58	SML-3A	29^{0}19'32" N	77^{0}21'04" E
8.		IM II	55	SML-3B	29^{0}19'31" N	77^{0}21'05" E
9.		TW	70	SML-3C	29^{0}19'16" N	77^{0}20'41" E
10.	Bhanera	HP	30	SML-4A	29^{0}16'23" N	77^{0}19'07" E
11.		IM II	61	SML-4B	29^{0}16'26" N	77^{0}19'02" E
12.		TW	58	SML-4C	29^{0}16'37" N	77^{0}19'07" E
13.	Kudana	HP	30	SML-5A	29^{0}25'53" N	77^{0}21'59" E
14.		IM II	73	SML-5B	29^{0}25'51" N	77^{0}22'01" E
15.		TW	53	SML-5C	29^{0}25'52" N	77^{0}21'58" E
16.	Kheri Bairagi	HP	62	SML-6A	29^{0}27'54" N	77^{0}23'01" E
17.		IM II	49	SML-6B	29^{0}27'55" N	77^{0}23'06" E
18.		TW	70	SML-6C	29^{0}27'53" N	77^{0}23'10" E
19.	Bantikhera	HP	21	SML-7A	29^{0}28'52" N	77^{0}24'04" E
20.		IM II	49	SML-7B	29^{0}28'50" N	77^{0}24'04" E
21.		TW	76	SML-7C	29^{0}28'31" N	77^{0}23'55" E
22.	Kairi	HP	30	SML-8A	29^{0}30'08" N	77^{0}24'10" E
23.		IM II	61	SML-8B	29^{0}30'09" N	77^{0}24'11" E
24.		BW(PS)	183	SML-8C	29^{0}30'21" N	77^{0}24'06" E
25.	Chandenamal	HP	14	SML-9A	29^{0}39'23" N	77^{0}27'22" E
26.		IM II	30	SML-9B	29^{0}39'18" N	77^{0}27'16" E
27.		BW(PS)	122	SML-9C	29^{0}39'17" N	77^{0}27'16" E
28.	Dabheri	HP	9	SML-10A	29^{0}38'26" N	77^{0}26'32" E
29.		IM II	30	SML-10B	29^{0}38'27" N	77^{0}26'31" E
30.		TW	61	SML-10C	29^{0}38'39" N	77^{0}26'47" E
31.	Jalalabad (R)	HP	21	SML-11A	29^{0}37'20" N	77^{0}26'28" E
32.		IM II	34	SML-11B	29^{0}37'17" N	77^{0}26'24" E
33.		BW(PS)	98	SML-11C	29^{0}37'17" N	77^{0}26'26" E
34.	Harad Fatehpur	HP	27	SML-12A	29^{0}33'08" N	77^{0}23'42" E
35.		IM II	61	SML-12B	29^{0}33'07" N	77^{0}23'41" E
36.		TW	76	SML-12C	29^{0}33'21" N	77^{0}23'59" E
37.	Raipur	HP	24	SML-13A	29^{0}31'59" N	77^{0}25'04" E
38.		IM II	55	SML-13B	29^{0}32'01" N	77^{0}25'03" E
39.		TW	61	SML-13C	29^{0}32'05" N	77^{0}25'10" E
40.	Masavi	HP	24	SML-14A	29^{0}34'25" N	77^{0}26'43" E
41.		IM II	40	SML-14B	29^{0}34'25" N	77^{0}26'43" E

HP – Private Hand Pump; IM II – India Mark II; TW – Tube Well; BW(PS) – Bore Well Piped Water Supply

Table 3.6 Description of Ground Water Sampling Locations in District Meerut

S.No.	Village	Source	Depth (m)	Sample ID	Lat	Long
1.	Baparsi	HP	30	MTC-1A	29^{0}10'41" N	77^{0}30'03" E
2.		IM II	37	MTC-1B	29^{0}10'41" N	77^{0}30'03" E
3.		IM II	37	MTC-1B2	29^{0}11'00" N	77^{0}29'47" E
4.		TW	55	MTC-1C	29^{0}10'57" N	77^{0}30'21" E
5.	Dhilaura	HP	9	MTC-2A	28^{0}57'41" N	77^{0}28'46" E
6.		IM II	37	MTC-2B	28^{0}57'41" N	77^{0}28'46" E
7.		TW	15	MTC-2C	28^{0}57'47" N	77^{0}28'52" E
8.	Alamgirpur Faridpur	HP	61	MTC-3A	29^{0}14'49" N	77^{0}34'24" E
9.		IM II	37	MTC-3B	29^{0}14'49" N	77^{0}34'24" E
10.		TW	12	MTC-3C	29^{0}14'33" N	77^{0}34'18" E

11.	Nahli	HP	18	MTC-4A	29^{0}13'13" N	77^{0}34'02" E
12.		IM II	37	MTC-4B	29^{0}13'13" N	77^{0}34'02" E
13.		TW	67	MTC-4C	29^{0}13'18" N	77^{0}34'08" E
14.	Pithlokar	HP	12	MTC-5A	29^{0}12'47" N	77^{0}32'06" E
15.		IM II	37	MTC-5B	29^{0}12'47" N	77^{0}32'06" E
16.		TW	49	MTC-5C	29^{0}12'05" N	77^{0}32'07" E

HP – Private Hand Pump; IM II – India Mark II; TW – Tube Well

Table 3.7 Description of Ground Water Sampling Locations in District Baghpat

S.No.	Village	Source	Depth (m)	Sample ID	Lat	Long
1.	Khaprana	HP	14	BPM-1A	29^{0}09'11" N	77^{0}27'59" E
2.		IM II	37	BPM-1B	29^{0}09'11" N	77^{0}27'59" E
3.	Galheta	HP	34	BPM-2A	29^{0}04'43" N	77^{0}26'01" E
4.		IM II	37	BPM-2B	29^{0}04'43" N	77^{0}26'01" E
5.	Himmatpur	HP	52	BPM-3A	29^{0}16'37" N	77^{0}19'43" E
6.		IM II	61	BPM-3B	29^{0}13'41" N	77^{0}19'35" E
7.		TW	79	BPM-3C	29^{0}13'41" N	77^{0}19'35" E
8.	Gangnoli	HP	43	BPM-4A	29^{0}12'10" N	77^{0}19'52" E
9.		IM II	61	BPM-4B	29^{0}12'10" N	77^{0}19'52" E
10.		TW	55	BPM-4C	29^{0}12'09" N	77^{0}19'55" E
11.	Bamnauli	HP	37	BPM-5A	29^{0}08'41" N	77^{0}21'00" E
12.		IM II	43	BPM-5B	29^{0}08'38" N	77^{0}21'09" E
13.		BW(PS)	122	BPM-5C	29^{0}08'36" N	77^{0}21'10" E
14.	Barnawa	HP	30	BPM-6A	29^{0}06'44" N	77^{0}25'36" E
15.		IM II	37	BPM-6B	29^{0}06'44" N	77^{0}25'36" E

HP – Private Hand Pump; IM II – India Mark II; TW – Tube Well; BW(PS) – Bore Well Piped Water Supply

Table 3.8 Description of Ground Water Sampling Locations in District Ghaziabad

S.No.	Village	Source	Depth (m)	Sample ID	Lat	Long
1.	Surana	HP	24	GZB-1A	28^{0}51'28" N	77^{0}25'10" E
2.		IM II	43	GZB-1B	28^{0}51'28" N	77^{0}25'10" E
3.		BW(PS)	76	GZB-1C	28^{0}51'34" N	77^{0}25'04" E
4.	Bhanera	HP	21	GZB-2A	28^{0}44'02" N	77^{0}22'50" E
5.		IM II	37	GZB-2B	28^{0}44'02" N	77^{0}22'50" E

HP – Private Hand Pump; IM II – India Mark II; BW(PS) – Bore Well Piped Water Supply

Table 3.9 Description of Ground Water Sampling Locations in District Gautambudh Nagar

S.No.	Village	Source	Depth (m)	Sample ID	Lat	Long
1.	Bisrakh Jalalpur	HP	49	GBN-1A	28^{0}34'12" N	77^{0}26'14" E
2.		IM II	37	GBN-1B	28^{0}34'12" N	77^{0}26'14" E
3.		BW	30	GBN-1C	28^{0}34'12" N	77^{0}26'14" E
4.	Surajpur	HP	46	GBN-2A	28^{0}30'49" N	77^{0}28'27" E
5.		IMII	37	GBN-2B	28^{0}30'50" N	77^{0}28'25" E
6.		BW	37	GBN-2C	28^{0}30'50" N	77^{0}28'26" E
7.	Momna Thal	HP	37	GBN-3A	28^{0}25'12" N	77^{0}30'09" E
8.		IM II	37	GBN-3B	28^{0}25'10" N	77^{0}30'10" E
9.		TW	9	GBN-3C	28^{0}25'35" N	77^{0}29'34" E

HP – Private Hand Pump; IM II – India Mark II; TW – Tube Well; BW – Bore Well

Field measurements like depth of water level, pH and electrical conductivity were measured at site using portable kits. The water samples for trace element analysis were collected in acid leached polyethylene bottles and preserved by adding ultra pure nitric acid (5 mL/lit.) and 0.1 N HCl for arsenic analysis. Samples for bacteriological analysis were collected in sterilized high density polypropylene bottles covered with aluminium foils while samples for pesticides analysis were collected in glass bottles as per the standard methods (APHA, 1992).

All the samples were stored in sampling kits maintained at 4^{o}C and brought to the laboratory for detailed physico-chemical and bacteriological analysis. The physico-chemical and bacteriological analysis were performed following APHA's Standard Methods for the Examination of Water and Wastewater Analysis (APHA, 1992). The GPS coordinates of all the sampling locations were measured using a high resolution GPS instrument for analyzing the data on GIS platform.

3.2 Chemicals and Reagents

All chemicals used for analysis were of analytical reagent grade (Merck/BDH). Standard solutions of metal ions were procured from Merck, Germany. Pesticide standards were procured from Sigma-Aldrich, USA. Bacteriological reagents were obtained from HiMedia. De-ionized water was used throughout the analysis work. All glassware and other containers used for trace element analysis were thoroughly cleaned by soaking in detergent followed by soaking in 10% nitric acid for 48 h and finally rinsed with de-ionized water several times prior to use. All glassware and reagents used for bacteriological analysis were thoroughly cleaned and sterilized before use. All glassware for pesticides analysis were rinsed with chromatography grade solvents prior to use.

3.3 Physico-chemical and Bacteriological Analysis

The physico-chemical and bacteriological analysis was performed as per standard methods (Jain and Bhatia, 1988; APHA, 1992). The details of analytical methods and equipment used in the study are described in Table 3.10. Ionic balance was calculated, the error in the ionic balance for majority of the samples was within 5%.

Table 3.10 Analytical Methods and Equipment Used in the Study

S.No.	Parameter	Method	Equipment
A.	**Physico-chemical**		
1.	pH	Electrometric	pH Meter
2.	Conductivity	Electrometric	Conductivity Meter
3.	TDS	Electrometric	Conductivity/TDS Meter
4.	Alkalinity	Titration by H_2SO_4	-
5.	Hardness	Titration by EDTA	-
6.	Chloride	Titration by $AgNO_3$	-
7.	Sulphate	Turbidimetric	Turbidity Meter

8.	Nitrate	Ultraviolet screening	UV-VIS Spectrophotometer
9.	Phosphate	Molybdophosphoric acid	UV-VIS Spectrophotometer
10.	Fluoride	SPADNS	UV-VIS Spectrophotometer
11.	Sodium	Flame emission	Flame Photometer
12.	Potassium	Flame emission	Flame Photometer
13.	Calcium	Titration by EDTA	-
14.	Magnesium	Titration by EDTA	-
15.	BOD	5 days incubation at 20^{o}C followed by titration	BOD Incubator
16.	COD	Digestion followed by titration	COD Digestor
B.	**Bacteriological**		
17.	Total coliform	Maximum Probable Number (MPN) method	Bacteriological Incubator
18.	Faecal coliform		
C.	**Heavy Metals**		
19.	Iron	Digestion followed by Atomic Spectrometry	Atomic Absorption Spectrometer
20.	Manganese		
21.	Copper		
22.	Nickel		
23.	Chromium		
24.	Lead		
25.	Cadmium		
26.	Zinc		
27.	Arsenic		
D.	**Pesticides**		
28.	Aldrin	Gas chromatography	Gas Chromatograph with ECD, NPD and FID
29.	DDE		
30.	DDD		
31.	α-BHC		
32.	β-BHC		
33.	γ-BHC		
34.	δ-BHC		
35.	Methoxychlor		
36.	Endosulphan		

3.4 Metal Ion Analysis

Perkin-Elmer Atomic Absorption Spectrometer (Model 3110) using air-acetylene flame was used for metal ion analysis. Average values of five replicates were taken for each determination. Operational conditions were adjusted in accordance with the manufacturer's guidelines to yield optimal determination. Quantification of metals was based upon calibration curves of standard solutions of respective metals. These calibration curves were determined several times during the period of analysis. The detection limits for iron, manganese, copper, nickel, chromium, lead, cadmium, zinc and arsenic are 0.003, 0.001, 0.001, 0.004, 0.002, 0.01, 0.0005, 0.0008 and 0.001 mg/L respectively.

3.5 Pesticide Analysis

The water samples for the analysis of organochloro-pesticide were extracted with n-hexane three times and the combined extract was concentrated using Kuderna Danish assembly under reduced vacuum. The moisture from the extracts was removed by using anhydrous sodium sulphate. The analysis of the organochloro-pesticides was carried using Aimil Nucon Gas Chromatograph with ECD detector. The column used was EQUITY-5, 30m with internal diameter of 0.25mm. Nitrogen gas was used as carrier gas at 2.0 ml/min with 28 ml/min as the makeup gas. The temperatures of the oven, detector and injector were 220, 250 and 270˚C, respectively. The qualitative and quantitative determination of the pesticides were carried out by comparing the retention time and peak area of the pesticides. The confirmation of the pesticides in the water samples was achieved by using standard internal addition method.

4.0 RESULTS AND DISCUSSION

4.1 River Water Quality

The hydro-chemical, trace element and pesticides data of the three rivers (Hindon-Kali-Krishni; Fig. 4.1) running through the project area are given in Tables 4.1 to 4.3 and discussed in the following sections.

4.1.1 River Hindon

The upper part of the river basin fall in Saharanpur District and have a large number of industries related to paper, milk products, distillery and small scale cottage industries pertaining to electroplating, paper board, chemicals and rubber, etc. The waste effluents generated from these industries are released either directly on the lowlands or into the tributaries of the Hindon River in their vicinity. Much of these wastes apparently contaminate the receiving water as can be sensed from the foul odours and anaesthetic colours especially in the stretches in the immediate downstream of their outfalls. The colour of the river water during entire stretch varies from brown to black with musty to rotten egg odour. Gas bubbles and foul odour of the stream indicates septic condition of the water body.

The main effluent discharge in the upper part of the river system is from Star Paper Mill, Saharanpur. The chemical analysis of the waste effluent shows that the effluent is rich in organic substances as reflected by high BOD and COD values (Jain et al., 2003). Besides this, the river has two major drains in its upper portion, viz., Nagdev nala and Dhamola nala, which join the River Hindon near the village of Ghogreki and Sadhauli Hariya, respectively. The municipal wastewater generated from the Saharanpur city is discharged to the Hindon River through Dhamola nala. There is no wastewater collection and treatment system in the city. In addition, the wastes from several small units such as textile factory, sugar factory, cigarette factory, card board factory and laundries etc. also transfer their wastes to the Hindon River through Dhamola nala.

In the mid portion of the basin, Kali River carrying the municipal and industrial effluents of Muzaffarnagar District join the Hindon River near the village of Atali. River Krishni receiving wastes from sugar mill and distillery joins River Hindon near the village of Barnawa. Besides these, some local drains from villages and towns also join the river. There are no notable waste outfalls in the lower portion of the study area. The characteristics of the various waste effluents/tributaries discharged into River Hindon have been reported in an earlier paper (Jain et al., 2002).

The River Hindon has not been abstracted at any place in its course of flow for organized water supply. The local fishermen use the river water for procuring fish, fish-seeds and fingerlings of several crops. The river is also utilized to flush the water of River Yamuna through Hindon cut canal in Delhi. The water quality of River Hindon has been monitored at 5 locations (Fig. 4.1) during present investigations.

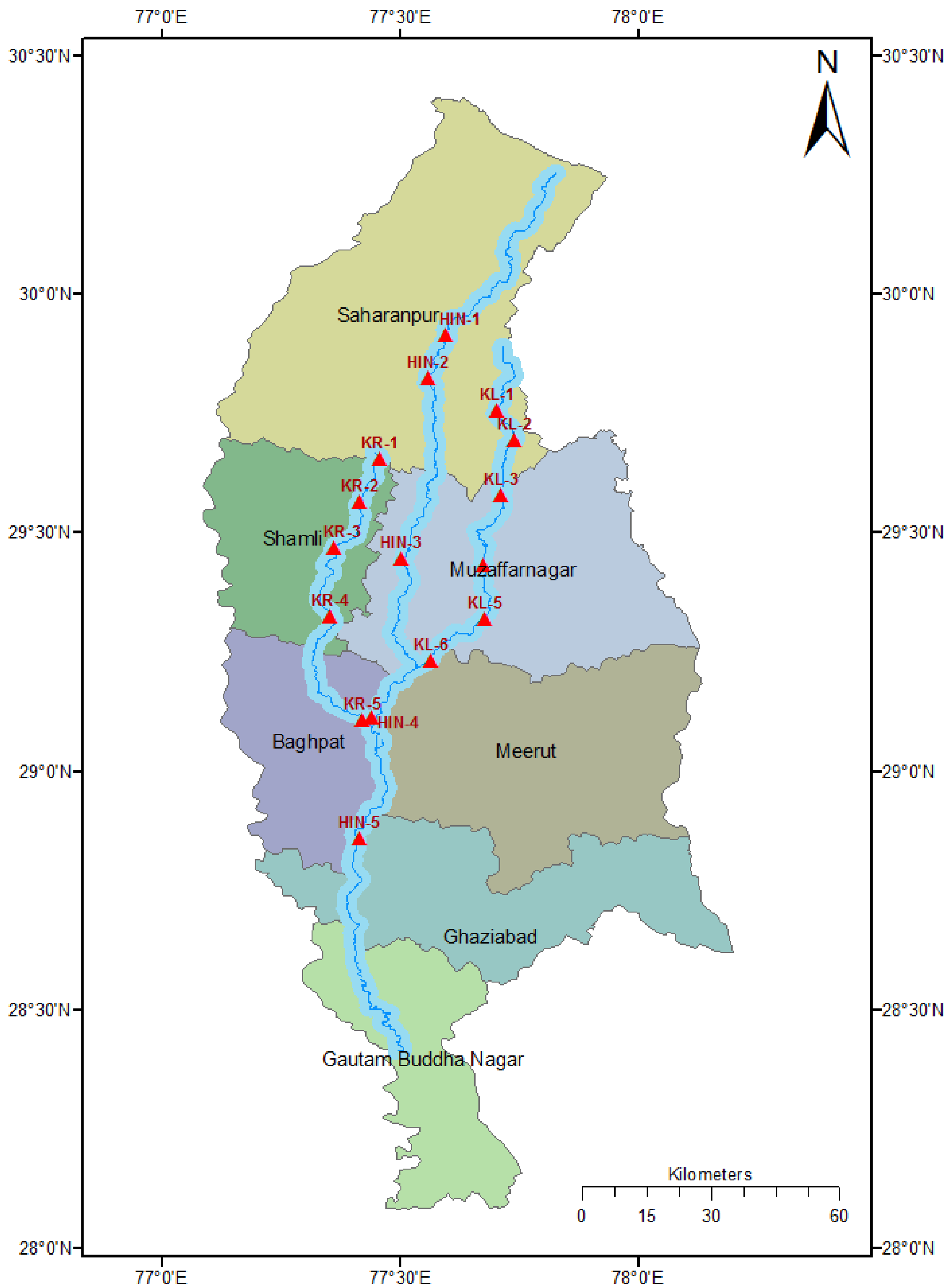


Fig. 4.1 River Hindon-Kali-Krishni Showing Location of River Sampling Points

Table 4.1 Hydro-chemical Data of River Hindon-Kali-Krishni (March 2013)

S.No.	Sample ID	Location	pH	EC	TDS	Alk	Hard	Na	K	Ca	Mg	HCO3	Cl	SO4	NO3	PO4	F	BOD	COD
				µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
River Hindon																			
1	HIN-1	Kapasa	6.9	3370	2157	1015	927	264	42	220	92	1238	256	25	11	0.69	ND	139	375
2	HIN-2	Tansipur	7.5	1572	1006	412	546	88	24	92	77	503	176	32	3.2	0.80	0.68	99	334
3	HIN-3	Atali	7.5	1756	1124	612	537	87	52	85	79	747	62	5.0	0.1	0.75	0.74	12	49
4	HIN-4	Barnawa	7.4	1865	1194	662	566	92	55	95	80	808	32	13	11	0.89	0.47	38	92
5	HIN-5	Surana	7.4	595	381	202	203	20	18	32	30	246	22	7.5	1.3	0.82	0.25	34	81
		Minimum	6.9	595	381	202	203	20	18	32	30	246	22	5.0	0.1	0.69	0.25	12	49
		Maximum	7.5	3370	2157	1015	927	264	55	220	92	1238	256	32	11	0.89	0.74	139	375
		Mean	7.3	1832	1172	581	556	110	38	105	72	708	110	17	5.3	0.79	0.54	64	186
River Kali																			
1	KL-1	Bahera Khas	7.5	690	442	242	236	34	1.3	42	32	295	12	14	5.8	0.18	0.37	22	52
2	KL-2	Palauli	8.4	669	428	236	231	27	4.4	58	21	288	14	13	0.5	0.26	0.33	36	64
3	KL-3	Rohana Khurd	8.2	755	483	264	253	31	5.8	62	24	322	10	20	3.7	0.34	0.58	56	128
4	KL-4	Sujru	7.1	818	524	275	300	32	9.6	64	34	336	24	18	0.4	0.39	0.54	108	245
5	KL-5	Jeevana	6.9	2408	1541	726	694	124	112	110	102	886	160	23	18	0.40	0.70	142	328
6	KL-6	Alam Girpur Faridpur	7.2	2817	1803	922	838	128	120	138	120	1125	140	23	0.1	0.42	0.49	186	442
		Minimum	6.9	669	428	236	231	27	1.3	42	21	288	10	13	0.1	0.18	0.33	22	52
		Maximum	8.4	2817	1803	922	838	128	120	138	120	1125	160	23	18	0.42	0.70	186	442
		Mean	7.6	1360	870	444	425	63	42	79	56	542	60	18	4.8	0.33	0.50	92	210
River Krishni																			
1	KR-1	Chandenamal	6.4	1212	776	408	426	14	67	72	60	498	52	7.5	0.4	0.26	0.49	134	265
2	KR-2	Raipur	7.0	498	319	152	175	14	13	39	19	185	16	30	0.1	0.34	0.43	84	202
3	KR-3	Kudana	7.2	2060	1318	705	404	185	59	76	52	860	40	28	12	0.44	ND	66	144
4	KR-4	Sunna	7.4	1015	650	312	301	56	21	68	32	381	44	35	6.8	0.62	0.70	42	96
5	KR-5	Barnawa	7.0	665	426	182	207	32	20	50	20	222	28	32	17	0.79	0.39	44	84
		Minimum	6.4	498	319	152	175	14	13	39	19	185	16	7.5	0.1	0.26	ND	42	84
		Maximum	7.4	2060	1318	705	426	185	67	76	60	860	52	35	17	0.79	0.70	134	265
		Mean	7.0	1090	698	352	303	60	36	61	37	429	36	27	7.3	0.49	0.50	74	158

Table 4.2 Trace Element Data of River Hindon-Kali-Krishni (March 2013)

S.No.	Sample ID	Location	Fe µg/L	Mn µg/L	Cu µg/L	Ni µg/L	Cr µg/L	Pb µg/L	Cd µg/L	Zn µg/L	As µg/L
River Hindon											
1	HIN-1	Kapasa	ND	429	36	131	63	90	30	12	2.069
2	HIN-2	Tansipur	85	264	9	ND	36	6	26	52	1.024
3	HIN-3	Atali	107	527	10	ND	29	33	27	86	1.158
4	HIN-4	Barnawa	90	459	18	ND	49	96	31	112	0.976
5	HIN-5	Surana	33	159	6	ND	7	93	3	46	0.469
		Minimum	33	159	6	ND	7	6	3	12	0.469
		Maximum	107	527	36	131	63	96	31	112	2.069
		Mean	79	368	16	131	37	64	23	62	1.139
River Kali											
6	KL-1	Banhera Khas	12	280	9	19	ND	ND	8	177	1.422
7	KL-2	Palauli	11	156	8	30	ND	43	8	112	1.102
8	KL-3	Rohana Khurd	7.0	238	7	31	20	57	12	158	1.308
9	KL-4	Sujru	7.0	79	10	ND	2.0	53	11	62	0.946
10	KL-5	Jeevana	24	334	11	50	25	87	18	98	1.169
11	KL-6	Alam Girpur Faridpur	3	454	10	94	13	95	13	112	0.865
		Minimum	3	79	7	ND	ND	ND	8	62	0.865
		Maximum	24	454	11	94	25	95	18	177	1.422
		Mean	11	257	9	45	15	67	12	120	1.135
River Krishni											
12	KR-1	Chandenamal	211	167	33	ND	29	37	10	64	ND
13	KR-2	Raipur	216	210	12	28	16	53	7	72	0.008
14	KR-3	Kudana	104	545	18	69	89	68	15	156	0.058
15	KR-4	Sunna	11	238	13	16	19	51	10	75	ND
16	KR-5	Barnawa	14	298	8	44	2	29	9	138	0.024
		Minimum	11	167	8	ND	2	29	7	64	ND
		Maximum	216	545	33	69	89	68	15	156	0.058
		Mean	111	292	17	39	31	48	10	101	0.030

Table 4.3 Pesticides Contamination in River Hindon-Kali-Krishni (March 2013)											
S.No.	Sample ID	Location	Organo-chlorinated Pesticides (μg/L)								
			Aldrin	α–BHC	β-BHC	γ-BHC	δ-BHC	DDD	DDE	Endosulphan	Methoxychlor
River Hindon											
1	HIN-1	Kapasa	~	~	~	~	~	~	~	~	~
2	HIN-2	Tansipur	~	~	~	~	~	~	~	~	~
3	HIN-3	Atali	~	~	~	~	~	~	~	~	~
4	HIN-4	Barnawa	~	~	~	~	~	~	~	~	~
5	HIN-5	Surana	~	~	~	~	~	~	~	~	~
River Kali											
6	KL-1	Bahera Khas	~	~	~	~	~	~	~	~	~
7	KL-2	Palauli	~	~	~	~	~	~	~	~	~
8	KL-3	Rohana Khurd	~	~	~	~	~	~	~	~	~
9	KL-4	Sujru	~	~	~	~	~	~	~	~	~
10	KL-5	Jeevana	~	~	~	~	~	~	~	~	~
11	KL-6	Alam Girpur Faridpur	~	~	~	~	~	~	~	~	~
River Krishni											
12	KR-1	Chandenamal	~	~	~	0.319	~	~	~	~	~
13	KR-2	Raipur	~	~	~	~	~	~	~	~	~
14	KR-3	Kudana	~	~	~	~	~	~	~	~	~
15	KR-4	Sunna	~	~	~	~	~	~	~	~	~
16	KR-5	Barnawa	~	~	~	0.176	~	~	~	~	~
~ = Below Detection Limit											

The colour of the river water during entire stretch varies from brown to black with musty to rotten egg odour due to the discharge of pulp and paper mill effluent. Gas bubbles and foul odour of the stream indicates septic condition of the water body. In addition to the floating froth and foam, the river water also becomes brown in colour owing to the discharge of effluent of pulp and paper factory. The brown colour of the water decreases the penetration of light and affects the spectrum of the wavelength, which penetrates into the river water. The change in the wavelength and its reduction in intensity limits the growth of phytoplankton and other aquatic plants which are of great importance, not only because they form an important link in the food-chain cycle of aquatic habitats, but they also produce oxygen by photosynthetic activity which plays an important role in reaeration of streams and in natural self-purification process.

The pH of the river water varies from 6.9 to 7.5 and was found towards alkaline at most of the sites. The contents of total dissolved solids vary 381 to 2157 mg/L with maximum TDS contant at Kapasa. This may be due to discharge of effluent from Star Paper Mill, Saharanpur. The excess dissolved solids creates an imbalance due to increased turbidity and causes suffocation to the fish life even in the presence of high dissolved oxygen. The decrease in TDS values in the downstream of Kapasa is due to confluence of domestic effluent stream from Saharanpur near village Sadhauli Hariya. Sudden decrease in TDS value at Surana was due to dilution of river water with irrigation canal water at Hariya Khera village.

The dissolved oxygen content in the upstream section of the river was quite satisfactory but a critical situation was observed after discharge of untreated municipal and industrial wastes from Nagdev nala and Star Paper Mill. The dissolved oxygen content gets reduced to zero and complete anaerobic condition is developed. This indicates that the river flow is mainly composed of the wastewater generated from the industries. The DO values gradually improve in the downstream section due to reaeration and photosynthesis (Jain et al., 2002, 2003).

The River Kali, carrying wastewater of municipal and industrial establishments of Muzaffarnagar District, meets River Hindon at village Atali thus augments the flow of the River Hindon. A substantial amount of water is discharged in River Kali from the Upper Ganga Canal at Khatauli. The level of dissolved oxygen in River Hindon after confluence with River Kali deteriorates further and observed to be nil during summer months. At village Barnawa, the another tributary Krishni joins River Hindon, which flows only during the sugar crushing season and remains stagnant for the rest of the year. In this stretch, the dissolved oxygen shows a large variation depending on the flow in the river. During summer months, the dissolved oxygen even gets reduced to nil at this station. The quality of the river water in this stretch is controlled by the discharge of water from the Upper Ganga Canal through Khatauli and Jani escapes (Jain et al., 2002, 2003).

The BOD of Hindon River varies from 12 to 139 mg/L during present investigations indicating high organic pollution load in the river. According to Central Pollution Control Board, BOD should not be more than 3 mg/L in water which is to be used for drinking and bathing. In order to conserve environment, BOD should be less than 10 mg/L to prevent odor caused by anaerobic decomposition of organic matter. The effluent of pulp and paper mill and distillery add to the high concentration of organic matter in the river, which is responsible for remarkable increase in BOD, COD and TDS.

The river is sluggish except during high flow period. It is evident that during high flow period, there is no significant effect of pollution owing to very high dilution of the effluent, but once the flow decreases, there is visible sign of pollution specifically during summer months. From the above discussion it is evident that the pollution load generated from Saharanpur town and industrial establishments of this region, viz. Star Paper Mill, Nagdev nala etc., is mainly responsible for the water quality degradation in the upper stretch of the Hindon Rriver. In the intermediate stretches, water quality shows a steady improvement due to reaeration and photosynthesis. Improvement in the river water quality in the downstream of the confluence of Dhamola nala indicates a relatively better quality of water in Dhamola nala compared to the river water. The river water before the confluence of Dhamola nala is mainly the mixture of wastewater of Nagdev nala and effluent from pulp and paper factory and distillery waste. A further improvement in the river water quality was noticed towards downstream of the river due to reaeration. In the lower stretch, degradation of water quality is observed due to the discharge of wastewater from Budhana drain, Kali River and Krishni River. However, the water quality in this stretch is mainly controlled by the release of water from Upper Ganga Canal through Khatauli and Jani escapes.

It is recommended that the wastewater generated by the municipal areas of Saharanpur, Muzaffarnagar and Ghaziabad should be treated before discharge into the river and/or utilized for irrigation through an organized network. Effluent treatment plants should be installed by the industrial units discharging their effluents directly into the river without any treatment.

The content of various trace elements have been monitored at five locations in River Hindon. The river transports significant amount of metal load. Out of eight point sources contributing to the River Hindon, River Kali contributes more than 50% of total metallic load to the River Hindon (Jain and Sharma, 2006). The river is highly influenced due to heavy metals, which enter the river system, by direct discharges of municipal and industrial effluents and surface runoff. Higher concentrations of metals in river water in the upper stretch are largely due to the mixing of effluent from Star Paper Mill. The elevated levels of trace metals in natural water systems pose a severe threat to the aquatic environment and also contaminate ground water resources.

The analysis of nine organo-chlorinated pesticides (Aldrin, α-BHC, β-BHC, γ-BHC, δ-BHC, DDD, DDE, Endosulphan and Methoxychlor) was also carried out on water samples collected from River Hindon but none of the pesticides was detected in any of the samples analyzed.

4.1.2 River Kali

The River Kali is a typical water course for municipal and industrial effluents. All those who have access to the river use it for bathing, laundry and even for defecating, and are very difficult to regulate. The main sources which create pollution in the river include, municipal waste of Muzaffarnagar City, waste from variety of industries (such as steel, rubber, ceramic, chemical, plastic, dairy, pulp and paper and loundaries) and Mansurpur sugar mill and distillery waste. The composite waste from variety of industries is transferred into the river through Muzaffarnagar main drain.

The major portion of the municipal wastewater of Muzaffarnagar City flows through a system of open drains and is discharged into the river at two points. One portion of the waste is discharged into the river near the village of Nayajupura while another portion of the waste having almost the same flow is discharged downstream of the bridge on Muzaffarnagar-Shamli road. At both the points, a lot of people and domestic animals (cows and buffalos) take bath and cloth washing activities are common just upstream of the outfalls of the municipal waste. From the point of view of river pollution and the deterioration of water quality in the bathing areas, the discharge from these drains is most critical.

Six water samples were collected and analysed during present investigations covering the entire stretch of River Kali during March 2013 (Fig. 4.1). The color of the river water during entire stretch varies from brown to black with gas bubbles and foul odor. The pH value of river water varies from 6.9 to 8.4. The total dissolved solids of river water vary from 428 to 1803 mg/L with maximum value at village Alam Girpur Faridpur. The increase in TDS at this location was due to discharge of industrial effluents from Mansurpur Sugal Mill and Begrajpur Industrial Area.

BOD and COD values of river water were in the range 22 to 186 and 52 to 442 mg/L respectively with maximum values at Alam Girpur Faridpur. The high BOD and COD values of the river water clearly indicate large scale disposal of untreated wastewater into the river. The discharge of municipal and industrial wastes at regular interval does not allow any self purification to occur. The amount of oxygen becomes a limiting factor when it is reduced by substances with a high oxygen demand. When a high load of organic matter is discharged into the river, its purification occurs in overlapping stages. Firstly, some portion of the waste undergoes immediate chemical oxidation. Secondly, there may be colloidal or suspended particles of organic nature which may be precipitated in the river and may undergo biological oxidation by the activity of bacteria and other microorganisms. Finally, anaerobic and aerobic oxidation of both soluble and deposited organic matter may occur. As the major part of this oxidation process is biochemical, the biochemical oxygen demand and dissolved oxygen gives a more complete picture of the nature and extent of pollution. Value of oxygen on the other hand furnishes an index to those organic substances which are oxidizable by acid permanganate at the specific time and temperature and may thus give an idea of the concentration of the substances which may undergo immediate chemical oxidation. Values of chemical oxygen demand, on the other hand, furnish an index to those organic substances which are oxidizable by the addition of oxidizing agent like potassium dichromate. Therefore, the addition of the municipal waste to the river result in the sudden increase in the biochemical oxygen demand accompanied by a sudden fall in the amount of dissolved oxygen, making the water unfit for many designated uses. It can be stated from the above discussion that the discharge of untreated municipal wastewater into the river is hazardous and results in significant deterioration of quality of the river water.

It is recommended that the wastewater/industrial effluents discharged directly into the river should be treated before their discharge into the river and/or utilized for irrigation through an organized network. Effluent treatment plants should be installed by the industrial units discharging their effluents directly into the river without any treatment.

The content of various trace elements have been monitored at six locations in River Kali. The river transports significant amount of metal load to the River Hindon. The river is highly influenced due to heavy metals, which enter the river system, by direct discharges of municipal and industrial effluents and surface runoff. The elevated levels of trace metals in natural water systems pose a severe threat to the aquatic environment and also contaminate ground water resources. It could be concluded from the present study that the treatment of waste effluents is necessary before discharging them into the river.

The analysis of nine organo-chlorinated pesticides (Aldrin, α-BHC, β-BHC, γ-BHC, δ-BHC, DDD, DDE, Endosulphan and Methoxychlor) was also carried out on water samples collected from River Kali but none of the pesticides was detected in any of the samples analyzed.

4.1.3 River Krishni

Five water samples were collected from River Krishni covering the entire stretch of the river during March 2013 (Fig. 4.1). The flow in the River Krishni is generated mainly from domestic and industrial wastewater. The color of the river water during entire stretch varies from brown to black with gas bubbles and foul odor. The pH of the river water varies from 6.4 to 7.4. The total dissolved solids in river water vary from 319 to 1318 mg/L with maximum value at village Kudana. The maximum value of TDS at this location is due to the discharge of industrial effluents from Sugal Mill and other industries.

BOD and COD values in the river water vary from 42 to 134 and 84 to 265 mg/L respectively with maximum values at Chandenamal. BOD values were more than 10 mg/L throughout the stretch indicating septic condition in the river.

The content of various trace elements have been monitored at five locations in River Krishni. The river transports significant amount of metal load to the River Hindon. The river is highly influenced due to heavy metals, which enter the river system, by direct discharges of municipal and industrial effluents and surface runoff. The elevated levels of trace metals in natural water systems pose a severe threat to the aquatic environment and also contaminate ground water resources. It could be concluded from the present study that the treatment of waste effluents is necessary before discharging them into the river.

The analysis of nine organo-chlorinated pesticides (Aldrin, α-BHC, β-BHC, γ-BHC, δ-BHC, DDD, DDE, Endosulphan and Methoxychlor) was also carried out on water samples collected from River Krishni and the results are given Table 4.3. Out of the nine chlorinated pesticides analysed, only one pesticide γ-BHC has been detected at two locations in the River Krishni. The presence of this pesticide in river water may be attributed to wash off from the agricultural fields during rainy season. The pesticide applied on surface might have leached through soil strata under the influence of hydraulic gradient and become source of contamination in river water.

4.2 Drinking Water Quality

The Bureau of Indian Standards (BIS) earlier known as Indian Standards Institution (ISI) has laid down the specifications for drinking water (BIS, 2012). This standard specifies the acceptable limits and the permissible limits in the absence of alternate source. It is recommended that the acceptable limit is to be implemented as values in excess of those mentioned under 'Acceptable' render the water not suitable. Such a water, however, be tolerated in the absence of alternate source. However, if the value exceeds the limit prescribed under 'Permissible' limit in the absence of alternate source, the sources will have to be rejected. The important water quality characteristics as laid down in BIS Standard are given in Table 4.4.

Table 4.4 Drinking Water Specifications (IS:10500:2012)

Drinking Water – Specifications (Second Revision) IS:10500:2012 © BIS 2012			
S.No.	Characteristics	Requirement (Acceptable Limit)	Permissible Limit in the Absence of Alternate Source
Table 1. Organoleptic and Physical Parameters			
i)	Colour, Hazen units, Max	5	15
ii)	Odour	Agreeable	Agreeable
iii)	pH value	6.5 to 8.5	No relaxation
iv)	Taste	Agreeable	Agreeable
v)	Turbidity, NTU, Max	1	5
vi)	Total dissolved solids, mg/L, Max	500	2000
Table 2.General Parameters Concerning Substances Undesirable in Excessive Amounts			
i)	Aluminium (as Al), mg/L, Max	0.03	0.2
ii)	Ammonia (as total ammonia-N), mg/L, Max	0.5	No relaxation
iii)	Anionic detergents (as MBAS), mg/L, Max	0.2	1.0
iv)	Barium (as Ba), mg/L, Max	0.7	No relaxation
v)	Boron (as B), mg/L, Max	0.5	1.0
vi)	Calcium (as Ca), mg/L, Max	75	200
vii)	Chloramines (as Cl_2), mg/L, Max	4.0	No relaxation
viii)	Chlorides (as Cl), mg/L, Max	250	1000
ix)	Copper (as Cu), mg/L, Max	0.05	1.5
x)	Fluoride (as F), mg/L, Max	1.0	1.5
xi)	Free residual chlorine, mg/L, Min	0.2	1
xii)	Iron (as Fe), mg/L, Max	0.3	No relaxation
xiii)	Magnesium (as Mg), mg/L, Max	30	100
xiv)	Manganese (as Mn), mg/L, Max	0.1	0.3
xv)	Mineral oil, mg/L, Max	0.5	No relaxation
xvi)	Nitrate (as NO_3), mg/L, Max	45	No relaxation

xvii)	Phenolic compounds (as C_6H_6OH), mg/L, Max	0.001	0.002
xviii)	Selenium (as Se), mg/L, Max	0.01	No relaxation
xix)	Silver (as Ag), mg/L, Max	0.1	No relaxation
xx)	Sulphate (as SO_4), mg/L, Max	200	400
xxi)	Sulphide (as H_2S), mg/L, Max	0.05	No relaxation
xxii)	Total Alkalinity (as $CaCO_3$), mg/L, Max	200	600
xxiii)	Total Hardness (as $CaCO_3$), mg/L, Max	200	600
xxiv)	Zinc (as Zn), mg/L, Max	5	15
Table 3. Parameters Concerning Toxic Substances			
i)	Cadmium (as Cd), mg/L, Max	0.003	No relaxation
ii)	Cyanide (as CN), mg/L, Max	0.05	No relaxation
iii)	Lead (as Pb), mg/L, Max	0.01	No relaxation
iv)	Mercury (as Hg), mg/L, Max	0.001	No relaxation
v)	Molybdenum (as Mo), mg/L, Max	0.07	No relaxation
vi)	Nickel (as Ni), mg/L, Max	0.02	No relaxation
vii)	Pesticides, µg/L, Max	See Table 5	No relaxation
viii)	Polychlorinated biphenyl, mg/L, Max	0.0005	No relaxation
ix)	Polynuclear aromatic hydrocarbons (as PAH), mg/L, Max	0.0001	No relaxation
x)	Total Arsenic (as arsenic), mg/L, Max	0.01	0.05
xi)	Total Chromium (as Cr), mg/L, Max	0.05	No relaxation
xii)	Trihalomethanes: a) Bromoform, mg/L, Max b) Dibromochloromethane, mg/L, Max c) Bromodichloromethane, mg/L, Max d) Chloroform, mg/L, Max	 0.1 0.1 0.06 0.2	 No relaxation No relaxation No relaxation No relaxation
Table 4. Parameters Concerning Radioactive Substances			
i)	Radioactive materials a) Alpha emitters, Bq/L, Max b) Beta emitters, Bq/L, Max	 0.1 1.0	 No relaxation No relaxation
Table 5. Pesticides Residues Limits			
S.No.	Pesticide	Limit	
i)	Alachlor, µg/L	20	
ii)	Atrazine, µg/L	2	
iii)	Aldrin / Dieldrin, µg/L	0.03	
iv)	Alpha HCH, µg/L	0.01	
v)	Beta HCH, µg/L	0.04	
vi)	Butachlor, µg/L	125	
vii)	Chlorpyriphos, µg/L	30	
viii)	Delta HCH, µg/L	0.04	
ix)	2,4-Dichlorophenoxyacetic acid, µg/L	30	
x)	DDT (o, p and p, p - Isomers of DDT, DDE	1	

	and DDD), μg/L	
xi)	Endosulfan (alpha, beta and sulphate), μg/L	0.4
xii)	Ethion, μg/L	3
xiii)	Gamma – HCH (Lindane), μg/L	2
xiv)	Isoproturon, μg/L	9
xv)	Malathion, μg/L	190
xvi)	Methyl parathion, μg/L	0.3
xvii)	Monocrotophos, μg/L	1
xviii)	Phorate, μg/L	2

Table 6. Bacteriological Quality of Drinking Water

S.No.	Organisms	Requirements
i)	All water intended for drinking: a) E.coli or thermotolerant coliform bacteria	 Shall not be detectable in any 100 ml sample
ii)	Treated water entering the distribution system a) E.coli or thermotolerant coliform bacteria b) Total coliform bacteria	 Shall not be detectable in any 100 ml sample Shall not be detectable in any 100 ml sample
iii)	Treated water in the distribution system a) E.coli or thermotolerant coliform bacteria b) Total coliform bacteria	 Shall not be detectable in any 100 ml sample Shall not be detectable in any 100 ml sample

In order to examine the quality of ground water of various drinking water sources, 202 ground water samples in the buffer zone of 2 km on the banks of River Hindon-Kali-Krishni covering seven districts namely Saharanpur, Muzaffarnagar, Shamli, Meerut, Baghpat, Ghaziabad and Gautambudh Nagar of Western Uttar Pradesh were collected and analyzed for various physico-chemical and bacteriological parameters, trace elements and organochlorine pesticides and results have been discussed in the following sections.

4.2.1 District Saharanpur

Total 68 ground water samples from private hand pumps, IM II hand pumps and tube wells/bore wells were collected from 28 villages in the buffer zone of 2 km on the banks of River Hindon and Kali falling in District Saharanpur (Fig. 4.2) and the results (Tables 4.5 to 4.7) are discussed in the following sections.

General Characteristics

The pH values in the ground water samples collected from District Saharanpur fall within the range of 6.8 to 8.2 in hand pumps, 7.2 to 8.0 in IM II hand pumps and 7.1 to 7.9 in tube wells/bore wells. The pH values for all of the samples are well within the limits prescribed by BIS (2012) for various uses of water including drinking and other domestic supplies.

The electrical conductivity and dissolved salt concentrations are directly related to the concentration of ionized substance in water and may also be related to problems of excessive hardness and/or other mineral contamination. The conductivity values in the ground water samples vary from 647 to 2866 μS/cm in hand pumps, 524 to 1970 μS/cm in IM II hand pumps and 596 to 1263 μS/cm in tube wells/bore wells. The conductivity values above 1000 μS/cm was observed in 50%, 7% and 1% samples of hand pumps, IM II hand pumps and tube wells/bore wells respectively. The maximum conductivity value of 2866 μS/cm was observed in the hand pump of village Shekhpura Kadim.

The TDS value in the ground water samples collected from District Saharanpur varies from 414 to 1834 mg/L in hand pumps, 335 to 1261 mg/L in IM II hand pumps and 381 to 808 mg/L in tube wells/bore wells. TDS values above the acceptable limit of 500 mg/L were observed in 86%, 50% and 42% samples of hand pumps, IM II hand pumps and tube wells/bore wells respectively. Water containing more than 500 mg/L of TDS is not considered acceptable for drinking water supplies, though more highly mineralized water is also used where better water is not available. For this reason, 500 mg/L as the acceptable limit and 2000 mg/L as the permissible limit has been suggested for drinking water (BIS, 2012). None of the collected samples from District Saharanpur exceeded the permissible limit of 2000 mg/L. Water containing TDS more than 500 mg/L causes gastrointestinal irritation.

Alkalinity in natural water is mainly due to presence of carbonates, bicarbonates and hydroxides. Bicarbonates represent the major form since they are formed in considerable amount from the action of carbonates upon the basic materials in the soil. The alkalinity value in the collected samples from District Saharanpur varies from 212 to 540 mg/L in hand pumps, 186 to 388 mg/L in IM II hand pumps and 212 to 338 mg/L in tube wells/bore wells. All the samples collected from hand pumps and tube wells/bore wells exceeded the acceptable limit of 200 mg/L but within the maximum permissible limit of 600 mg/L.

Hardness of water is due to carbonates, sulphates and chlorides of calcium and magnesium. A limit of 200 mg/L as acceptable limit and 600 mg/L as permissible limit has been recommended for drinking water (BIS, 2012). The total hardness values in the samples collected from District Saharanpur range from 240 to 870 mg/L in hand pumps, 185 to 477 mg/L in IM II hand pumps and 227 to 444 mg/L in tube wells/bore wells. The ground water samples from hand pumps of Paragpur, Kapasa, Shekhpura Kadim and Sanpla Khatri exceeds the permissible limit of 600 mg/L.

In ground water of the samples collected from District Saharanpur, the values of calcium range from 40 to 202 mg/L in hand pumps, 36 to 112 mg/L in IM II hand pumps and 45 to 97 mg/L in tube wells/bore wells and the values of magnesium range from 13 to 101 mg/L in hand pumps, 15 to 48 mg/L in IM II hand pumps and 14 to 52 mg/L in tube wells/bore wells. The acceptable limit for calcium and magnesium for drinking water are 75 and 30 mg/L respectively (BIS, 2012). In ground water, the calcium content generally exceeds the magnesium content in accordance with their relative abundance in rocks. Further, ground water sample from hand pump of Kapasa exceeds the maximum permissible limit of 200 mg/L for calcium and ground water sample from hand pump of Shekhpura Kadim exceeded the permissible limit of 100 mg/L for magnesium.

The concentration of sodium in the samples collected from District Saharanpur varies from 7.7 to 308 mg/L in hand pumps, 8.3 to 229 mg/L in IM II hand pumps and 11 to 63 mg/L in tube wells/bore wells. The Bureau of Indian Standards has not included sodium in drinking water standards. The high sodium values in the collected samples may be attributed to base-exchange phenomena and causes sodium hazard. Ground water with such high sodium is not suitable for irrigation purpose.

Potassium is an essential element for humans, plants and animals and derived in food chain mainly from vegetation and soil. The main sources of potassium in ground water include rain water, weathering of potash silicate minerals, use of potash fertilizers and use of surface water for irrigation. The concentration of potassium in the ground water samples collected from District Saharanpur varies from 1.8 to 37 mg/L in hand pumps, 2.7 to 12 mg/L in IM II hand pumps and 2.2 to 6.5 mg/L in tube wells/bore wells. The Bureau of Indian Standards has not included potassium in drinking water standards. However, the European Economic Community has prescribed guideline level of potassium at 10 mg/L in drinking water. As per EEC criteria, ground water samples from hand pump and IM II hand pumps of Paragpur, hand pumps of Kapasa, Shekhpura Kadim and Tanshipur exceeded the guideline level of 10 mg/L.

The concentration of chloride in the samples collected from District Saharanpur varies from 4.0 to 504 mg/L in hand pumps, 4.0 to 428 mg/L in IM II hand pumps and 4.0 to 120 mg/L in tube wells/bore wells. Samples from hand pump and IM II hand pumps of Paragpur and IM II hand pumps of Shekhpura Kadim exceed the desirable limit of 250 mg/L. The limits of chloride have been laid down primarily from taste considerations. A limit of 250 mg/L chloride has been recommended as acceptable limit and 1000 mg/L as the permissible limit for drinking water (BIS, 2012). However, no adverse health effects on humans have been reported from intake of waters containing even higher content of chloride.

The concentration of sulphate in the samples collected from District Saharanpur varies from 3.0 to 215 mg/L in hand pumps, 1.5 to 130 mg/L in IM II hand pumps and 1.0 to 55 mg/L in tube wells/bore wells. Bureau of Indian Standard has prescribed 200 mg/L as the acceptable limit and 400 mg/L as the permissible limit for sulphate in drinking water. In the samples collected from District Saharanpur, only one sample from hand pump of Paragpur exceeded the maximum acceptable limit of 200 mg/L and none of the samples exceeded the maximum permissible limit of 400 mg/L. The sulphate content in ground water generally occurs as soluble salts of calcium, magnesium and sodium.

Nitrate content in drinking water is considered important for its adverse health effects and moderately toxicity. A limit of 45 mg/L has been prescribed by BIS (2012) for drinking water supplies. Its concentration above 45 mg/L may prove detriment to human health. In higher concentrations, nitrate may produce a disease known as methaemoglobinaemia (blue babies) which generally affects bottle-fed infants. Repeated heavy doses of nitrates on ingestion may also cause carcinogenic diseases. The nitrate content in the samples collected from District Saharanpur varies from 0 to 163 mg/L in hand pumps, 0 to 25 mg/L in IM II hand pumps and 0 to 13 mg/L in tube wells/bore wells. The nitrate concentration was observed more than permissible limit of 45 mg/L in ground water samples from hand pumps of villages Paragpur, Hasanpur Banaswa, Shekhpura Kadim, Lakhnour and Shitala Khera, which may be attributed to contamination by industrial/domestic waste disposal.

The presence of fluoride in ground water may be attributed to the localized effects of natural sources. The fluoride is present in soil strata due to the presence of geological formations like fluorspar, fluorapatite, ampheboles such as hornblinde, trimolite and mica. Weathering of alkali, silicate, igneous and sedimentary rocks specially shales contribute a major portion of fluorides to ground waters. In addition to natural sources, considerable amount of fluorides may be contributed due to man's activities. Fluoride salts are commonly used in steel, aluminium, bricks and tile-industries. The fluoride containing insecticides and herbicides may be contributed through agricultural runoff. Phosphatic fertilizers, which are extensively used, often contain fluorides as impurity and these may increase levels of fluoride in soil. The accumulation of fluoride in soil eventually results in its leaching due to percolating water, thus increase fluoride concentration in ground water. The fluoride content in the ground water samples collected from District Saharanpur varies from 0.01 to 0.34 mg/L in hand pumps, 0 to 0.58 mg/L in IM II hand pumps and 0 to 0.38 mg/L in tube wells/bore wells. Ground water samples collected from all villages of the District Saharanpur fall within the acceptable limit of 1.0 mg/L.

From the above discussion, it is clearly evident that in the ground water samples collected from District Saharanpur, the concentration of total dissolved solids was observed above the acceptable limit of 500 mg/L in more than 86%, 50% and 42% samples of hand pumps, IM II hand pumps and tube wells/bore wells respectively but none of the samples exceeded the permissible limit of 2000 mg/L. The hardness values also observed to exceed the permissible limit in ground water samples from the hand pumps of villages Paragpur, Kapasa, Shekhpura Kadim and Sanpla Khatri. The concentration of nitrate exceeded the permissible limit in ground water samples from the hand pumps of villages Paragpur, Hasanpur Banaswa, Shekhpura Kadim, Lakhnour and Shitala Khera. The concentration of fluoride was observed within the acceptable limit. The violation of BIS limit could not be ascertained for sodium and potassium as no permissible limit for these constituents has been prescribed in BIS drinking water specifications. On the basis of above results, it can be inferred that ground water from hand pumps have the problem of TDS, hardness and nitrate specially in the area of Paragpur and Shekhpura Kadim, which may be attributed to possible impact of effluents from Nagdev Nala and Star Paper Mill drain on the ground water.

Bacteriological Parameters

In water quality control technology, the principal indicator of suitability of water for domestic, industrial or other uses is the coliform group of bacteria. The density of coliform group is the criteria for the extent of contamination and has been the basis for bacteriological water quality standard. Further, the presence of faecal colifirms in water is the indicator of a potential public health problem, because faecal matter is a source of pathogenic bacteria and viruses. The faecal coliform bacteria contaminate water through percolation from contamination sources (domestic sewage and septic tank) and also because of poor sanitary system. The indiscriminate land disposal of domestic waste on surface and improper disposal of solid waste further aggravate the problem of bacterial contamination in water. The collected samples from District Saharanpur were analysed for bacteriological parameters viz; Total Coliform and Faecal Coliform. The result of bacteriological analysis is given in Table 4.6. The result shows that the bacterial contamination was observed in six ground water samples collected from the District Saharanpur.

Heavy Metals

Heavy metals in ground water have a considerable significance due to their toxicity and adsorption behaviour. Heavy metals are not biodegradable and enter the food chain through a number of pathways causing progressive toxicity due to the accumulation in human and animal organs during their life span on long term exposure to contaminated environments. Despite the presence of trace concentrations of Cr, Mn, Co, Cu and Zn in the aquatic environment, which is essential to a number of life processes, high concentrations of these metals become toxic. The major sources of heavy metals in ground water include weathering of rock minerals, discharge of sewage and other waste effluents on land and runoff water. The trace element data of ground water samples collected from the District Saharanpur is given in Table 4.7. The distribution of different metals is shown graphically in Fig. 4.3. The toxic effects of these elements and extent of their contamination in ground water is discussed in the following sections.

Iron (Fe): The concentration of iron in the ground water samples collected from District Saharanpur ranges from 0.106 to 24.188 mg/L in hand pumps, 0.210 to 20.128 mg/L in IM II hand pumps and 0.040 to 2.243 mg/L in tube wells/bore wells. The Bureau of Indian Standards has recommended 0.3 mg/L as the acceptable limit for iron in drinking water (BIS, 2012). WHO has prescribed 0.3 mg/L as the acceptability threshold value for iron (WHO, 2011). It is evident from the results that 85% samples of hand pumps and IM II hand pumps and about 35% of tube wells/bore wells exceed the acceptable limit of 0.3 mg/L. Very high concentration of iron was observed in the ground water of Ibrahimpur, Paragpur, Shekhpura Kadim, Lakhnour, Rasoolpur Kheri, Sadauli Hariya, Tanshipur, Shitala Khera, Maheshpur, Mahmoodpur, Banhera Khas, Palauli and Matauli. The higher concentration of iron in the ground water upto Maheshpur may be attributed to leaching of wastes from Nagdev nala, Star paper mill drain and Dhamola drain.

It is a known fact that iron in trace amounts is essential for nutrition. High concentrations of iron generally cause inky flavour, bitter and astringent taste to water. Well water containing soluble iron remain clear while pumped out, but exposure to air causes precipitation of iron due to oxidation, with a consequence of rusty colour and turbidity. The objection to iron in the distribution system is not due to health reason but to staining of laundry and plumbing fixtures and appearance. Taste and order problems may be caused by filamentous organism that prey on iron compounds (frenothrix, gallionella and leptothrix are called iron bacteria), originating another consumer's objection (red water). The presence of iron bacteria may clog well screens or develop in the distribution system, particularly when sulphate compounds in addition to iron may be subjected to chemical reduction.

Manganese (Mn): The concentration of manganese in the ground water samples collected from District Saharanpur ranges from 0.006 to 2.274 mg/L in hand pumps, 0.049 to 0.974 mg/L in IM II hand pumps and 0.059 to 0.301 mg/L in tube wells/bore wells. Manganese is an essential trace nutrient for plants and animals, which does not occur naturally as a metal but is found in various salts and minerals frequently in association with iron compounds. Manganese may gain entry into the body by inhalation, consumption of food and through drinking water. A concentration of 0.1 mg/L has been recommended as an acceptable limit and 0.3 mg/L as the permissible limit for drinking water (BIS, 2012). WHO has prescribed 0.1 mg/L as the acceptability threshold value and 0.4 mg/L as health based value (WHO, 2011). It is evident from the results that 15% of the samples collected each from the hand pumps and IM II hand pumps and 30% samples from tube wells/bore wells fall within the acceptable limit of 0.1 mg/L and more than 25% samples each from hand pumps and IM II hand pumps exceeds the maximum permissible limit of 0.3 mg/L. The presence of manganese above permissible limit of drinking water often imparts alien taste to water. It also has adverse effects on domestic uses and water supply structures.

Copper (Cu): The concentration of copper in the ground water samples collected from District Saharanpur ranges from 0.004 to 0.952 mg/L in hand pumps, 0.005 to 0.032 mg/L in IM II hand pumps and 0.005 to 0.027 mg/L in tube wells/bore wells. The Bureau of Indian Standards has recommended 0.05 mg/L as the acceptable limit and 1.5 mg/L as the permissible limit in the absence of alternate source (BIS, 2012). Beyond 0.05 mg/L the water imparts astringent taste and cause discoloration and corrosion of pipes, fittings and utensils. World Health Organization has recommended 2.0 mg/L as the provisional guideline value for drinking purpose (WHO, 2011). In the present investigation, two samples collected from hand pumps of District Saharanpur exceed the acceptable limit of 0.05 mg/L.

Nickel (Ni): The concentration of nickel in the ground water samples collected from District Saharanpur ranges from ND to 0.116 mg/L in hand pumps, ND to 0.102 mg/L in IM II hand pumps and ND to 0.067 mg/L in tube wells/bore wells. The Bureau of Indian Standards has recommended 0.02 mg/L as the acceptable limit (BIS, 2012). World Health Organization has recommended 0.07 mg/L as the guideline value for drinking purposes (WHO, 2011). In this range it is not harmful in drinking water. More than 60% samples each from hand pumps, IM II hand pumps and bore wells/tube wells exceed the BIS limit of 0.02 mg/L.

Chromium (Cr): The concentration of chromium in the ground water samples collected from District Saharanpur ranges from ND to 0.083 mg/L in hand pumps, ND to 0.066 mg/L in IM II hand pumps and ND to 0.050 mg/L in tube wells/bore wells. A concentration of 0.05 mg/L has been recommended as an acceptable limit for drinking water (BIS, 2012). WHO has also prescribed 0.05 mg/L as the guideline value for drinking water (WHO, 2011). Six samples from hand pumps and three samples from IM II hand pumps exceed the BIS limit of 0.05 mg/L. which may be attributed to leaching of chrome bearing waste from industries.

Hexavalent chromium has a deleterious effect on the liver, kidney and respiratory organs with hemorrhagic effects, dermatitis and ulceration of the skin for chronic and subchronic exposure. Municipal wastewater release considerable amount of chromium into the environment. In the natural environment, Cr(+6) is likely to be reduced to Cr(+3), thereby reducing the toxic impact of chromium discharges. The pathways of chromium contribution to ground water are that the chromium containing industrial effluent discharged into stream, the hexavalent state chromium may be reduced to trivalent state and later adsorbed on the suspended particulate. In case, it could not be adsorbed, the chromium remain in the form of colloidal suspension, may precipitate and become part of stream sediment, from where it may reach to ground water through percolation containing shallow aquifers.

Lead (Pb): In the ground water samples collected from District Saharanpur, the concentration of lead ranges from ND to 0.110 mg/L in hand pumps, ND to 0.102 mg/L in IM II hand pumps and ND to 0.090 mg/L in tube wells/bore wells. The Bureau of Indian Standards has prescribed 0.01 mg/L lead as the desirable limit for drinking water (BIS, 2012). Beyond this limit, the water becomes toxic. WHO has also prescribed 0.01 mg/L as guideline value for drinking water (WHO, 2011). More than 60% samples each from hand pumps and IM II hand pumps and 90% samples from tube wells/bore wells exceed the BIS limit of 0.01 mg/L.

Lead is not considered an essential nutritional element and is a cumulative poison to humans. Acute lead poisoning is extremely rare. The typical symptoms of advanced lead poisoning are constipation, anemia, gastrointestinal disturbance, tenderness and gradual paralysis in muscles, specifically arms with possible cases of lethargy and moroseness. The major source of lead contamination is the combustion of fossil fuel. Lead is removed from the atmosphere by rain and falls back on the earth surface and seeps into the ground. Lead passes from the soil to water and to the plants and finally into the food chain. In drinking water it occurs primarily due to corrosion of lead pipes and solders, especially in areas of soft water. It may be noted that the use of soft water of slightly acidic pH and the use of lead pipes in service and domestic water lines may provide higher concentrations of lead at the consumers’s tap, particularly when the water use is minimal in the household (overnight still water in pipes).

Cadmium (Cd): In the ground water samples collected from District Saharanpur, the concentration of cadmium ranges from ND to 0.015 mg/L in hand pumps, ND to 0.008 mg/L in IM II hand pumps and ND to 0.012 mg/L in tube wells/bore wells. The Bureau of Indian Standards has prescribed 0.003 mg/L cadmium as the acceptable limit for drinking water (BIS, 2012). WHO has also prescribed 0.003 mg/L cadmium as the guideline value for drinking water (WHO, 2011). The drinking water having more than 3 μg/L of cadmium can cause bronchitis, emphysema, anaemia and renal stone formation in animals. More than 60% samples each from hand pumps and tube wells/bore wells and about 45% samples from IM II hand pumps exceed the BIS limit of 0.003 mg/L.

Zinc (Zn): The concentration of zinc in the ground water samples collected from District Saharanpur ranges from 0.042 to 1.080 mg/L in hand pumps, 0.095 to 1.099 mg/L in IM II hand pumps and 0.115 to 0.564 mg/L in tube wells/bore wells. The Bureau of Indian Standards has prescribed 5.0 mg/L zinc as the acceptable limit and 15 mg/L as the permissible limit for drinking water (BIS, 2012). WHO has prescribed 3.0 mg/L as the guideline value for drinking water (WHO, 2011). All the samples were found within the desirable limit prescribed by BIS (2012) and WHO (2011).

Arsenic (As): In the ground water samples collected from District Saharanpur, the concentration of arsenic was not detected. Ground water is expected to contain higher arsenic concentrations than surface water. Because of its presence in geological materials, arsenic can be traced in water as originated by natural processes or by industrial activities – industrial waste, arsenical pesticides and smelting operations. Generally, arsenic found in two state, As(III) and As(V) in ground water. As(III) compounds are more toxic than As(V) compounds. Arsenic compounds are skin and lung carcinogens in humans. The Bureau of Indian Standards has prescribed 0.01 mg/L arsenic as the acceptable limit and 0.05 mg/L as the permissible limit for drinking water (BIS, 2012). WHO has prescribed 0.01 mg/L arsenic as the guideline value for drinking water (WHO, 2011). In the present investigation, all the ground water samples collected from District Saharanpur were found within the acceptable limit as prescribed by BIS (2012).

From the above results, it is quite clear that the presence of heavy metals has been recorded at many location and the water quality standards have been violated for iron (24 samples from hand pumps, 25 samples from IM II hand pumps and 4 samples from tube wells/bore wells), manganese (10 samples from hand pumps, 8 samples from IM II hand pumps and 1 samples from tube wells/bore wells), copper (2 samples from hand pumps), nickel (21 samples from hand pumps, 17 samples from IM II hand pumps and 8 samples from tube wells/bore wells), chromium (6 samples from hand pumps and 3 samples from IM II hand pumps), lead (21 samples from hand pumps, 17 samples from IM II hand pumps and 11 samples from tube wells/bore wells), Cadmium (21 samples from hand pumps, 12 samples from IM II hand pumps and 8 samples from tube wells/bore wells) out of total 28 samples from hand pumps, 28 samples from IM II hand pumps and 12 samples from tube wells/bore wells of the district.

Pesticides

The analysis of nine organo-chlorinated pesticides (Aldrin, α-BHC, β-BHC, γ-BHC, δ-BHC, DDD, DDE, Endosulphan and Methoxychlor) was carried out in ground water samples from IM II hand pump of Hasanpur Banaswa and Shekhpura Kadim of Saharanpur District. Out of the nine chlorinated pesticides analysed, only two pesticides γ-BHC (1.025 μg/L) and Methoxychlor (0.602 μg/L) have been detected in the ground water of Hasanpur Banaswa and Shekhpura Kadim respectively. The concentration of γ-BHC pesticide was observed within the permissible limit. The presence of these pesticides in ground water may be attributed due to their use in agricultural activities and for vector control programmes. The pesticide applied on surface might have leached through soil strata under the influence of hydraulic gradient and become source of contamination in ground water.

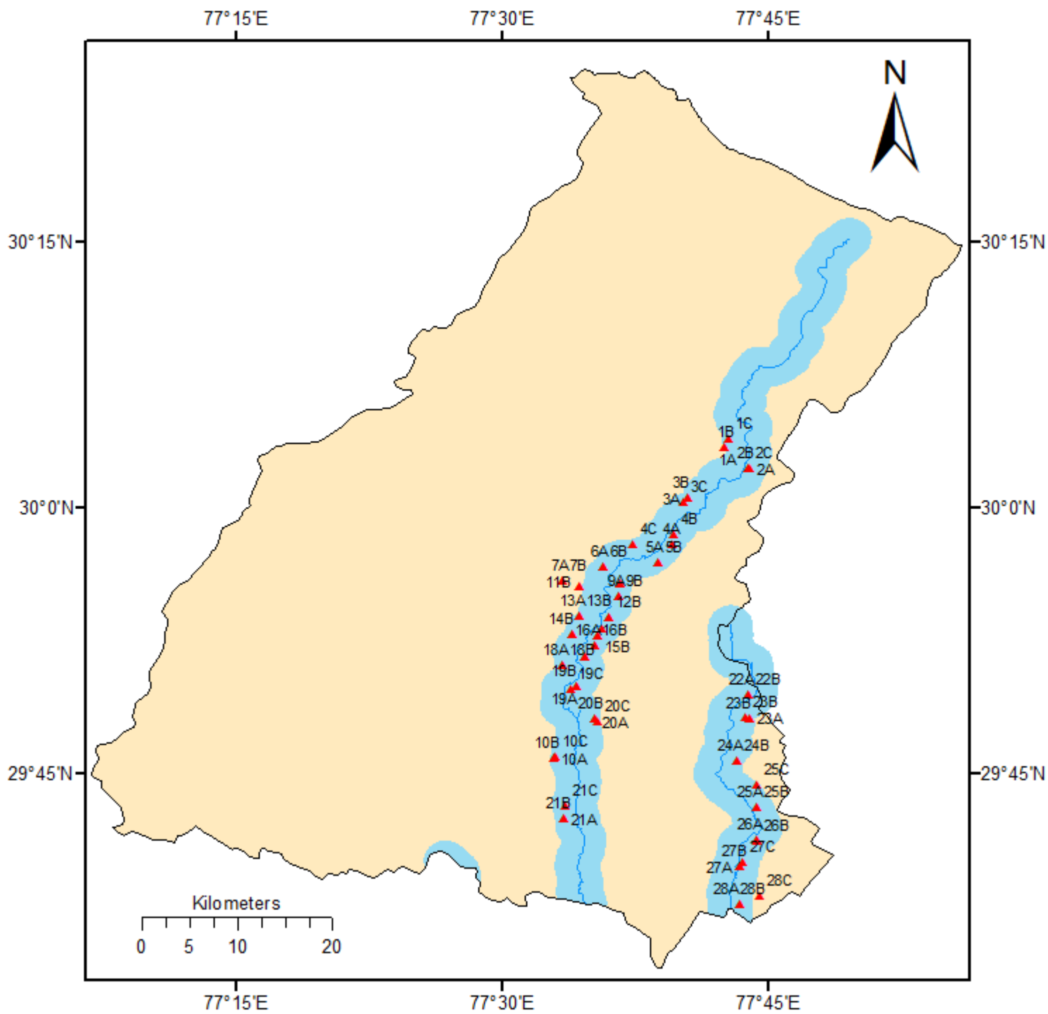


Fig. 4.2 Ground Water Sampling Locations in District Saharanpur in Two km Buffer Zone of River Hindon and Kali

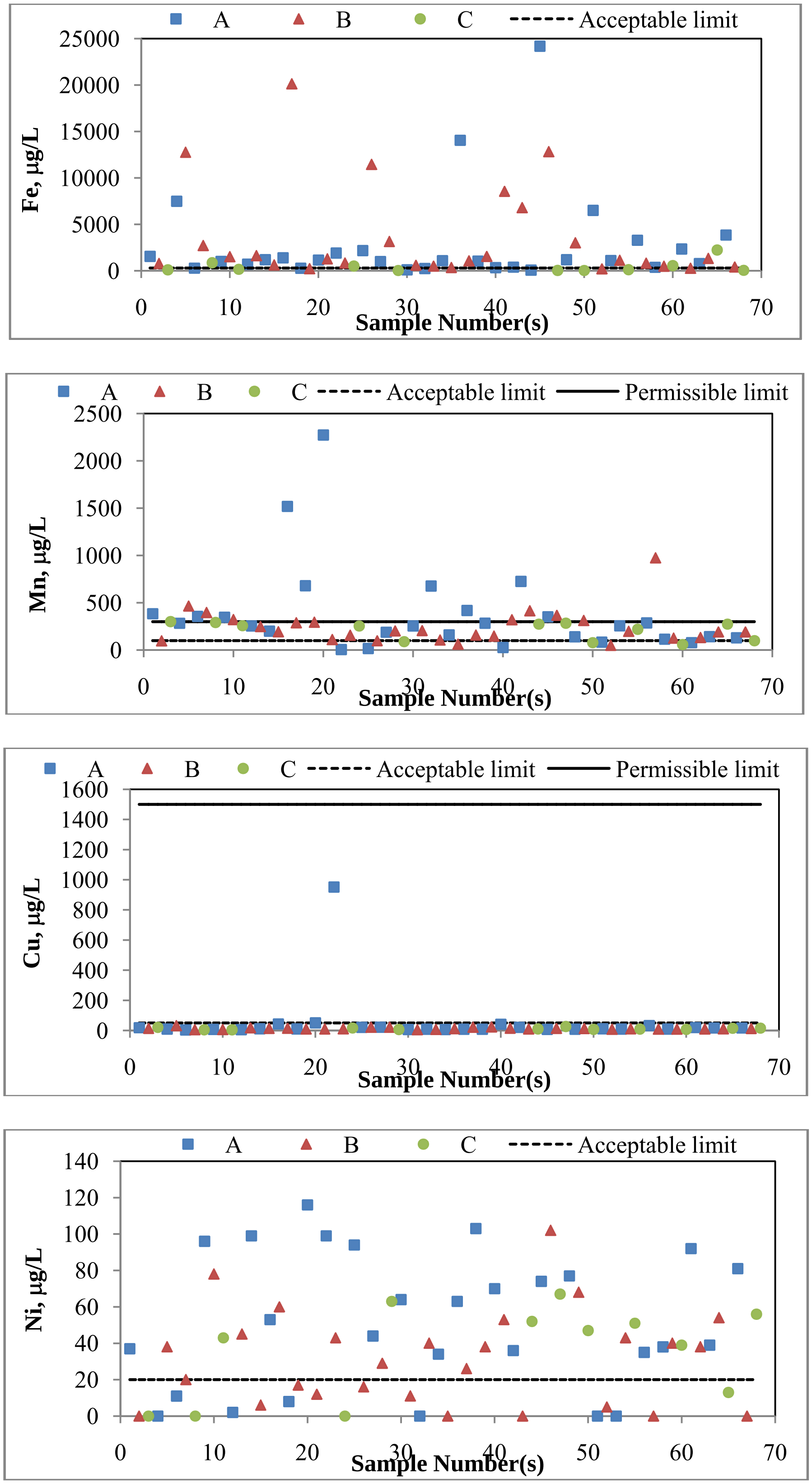


Fig. 4.3 Distribution of Trace Elements in Ground Water of District Saharanpur

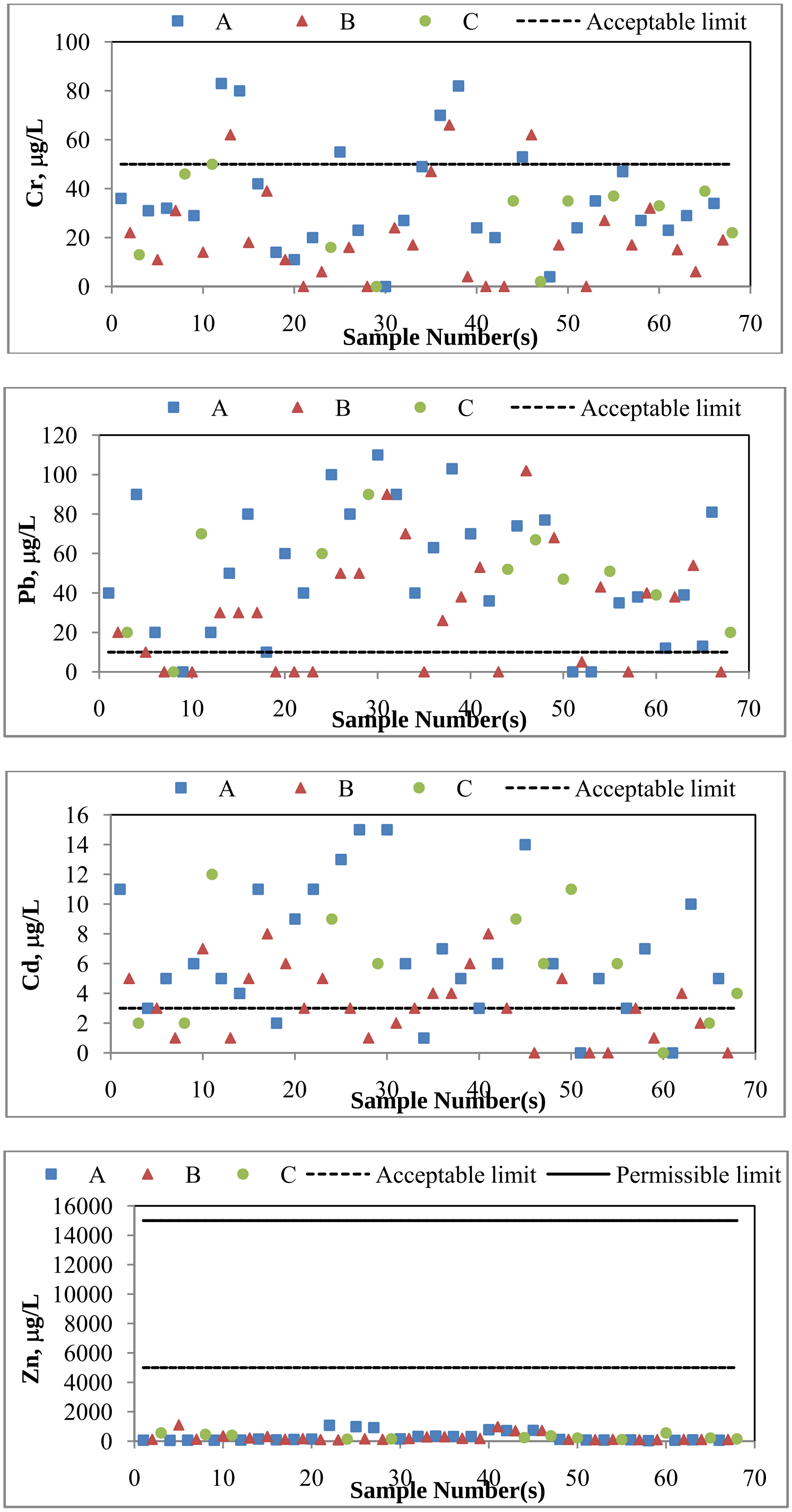


Fig. 4.3 (Contd.) Distribution of Trace Elements in Ground Water of District Saharanpur

Table 4.5 Hydro-chemical Data of Ground Water Samples of District Saharanpur (March 2013)

S.No.	Sample ID	Location	Source	Depth	pH	EC	TDS	Alk	Hard	Na	K	Ca	Mg	HCO3	Cl	SO4	NO3	PO4	F	BOD	COD
				m		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1	SRE-1A	Sarda Heri	HP	31	7.1	972	622	372	325	31	6.1	76	33	454	16	3.0	0	0.08	0.01	0.9	4.9
2	SRE-1B	Sarda Heri	IM II	37	7.5	994	636	388	362	24	2.7	66	48	473	18	1.5	0	0.04	0.48	0.6	3.8
3	SRE-1C	Sarda Heri	TW	137	7.4	858	549	322	276	39	2.2	48	38	393	22	4.0	0	0.02	0.06	0.2	1.8
4	SRE-2A	Ibrahimpur	HP	21	7.2	765	490	252	294	20	3.2	55	38	307	58	3.5	0.8	0.06	ND	0.1	1.2
5	SRE-2B	Ibrahimpur	IM II	37	7.5	940	602	318	345	27	3.5	74	39	388	52	14	1.0	0.04	ND	0.5	2.5
6	SRE-3A	Pali	HP	46	7.3	652	417	235	254	16	3.3	54	29	287	16	7.0	2.6	0.07	0.34	1.0	4.5
7	SRE-3B	Pali	IM II	37	7.4	695	445	273	243	18	3.4	48	30	333	6.0	3.5	0	0.04	0.13	1.0	4.4
8	SRE-3C	Pali	TW	56	7.2	758	485	288	261	22	4.1	52	32	351	12	7.5	0	0.03	0.35	0.9	3.9
9	SRE-4A	Gagalhedi	HP	18	7.0	1002	641	342	361	33	3.7	110	21	417	36	18	0	0.06	0.06	1.5	3.5
10	SRE-4B	Gagalhedi	IM II	37	7.4	637	408	228	255	14	2.9	41	37	278	8.0	23	0	0.02	0.51	0.9	3.1
11	SRE-4C	Gagalhedi	TW	40	7.3	813	520	282	261	38	4.1	52	32	344	24	24	0	0.01	ND	0.8	4.5
12	SRE-5A	Khazoori Akbarpur	HP	20	7.3	986	631	360	341	36	6.4	92	27	439	14	10	2.7	0.08	0.32	0.9	3.2
13	SRE-5B	Khazoori Akbarpur	IM II	37	7.7	648	415	234	248	16	3.1	60	24	285	12	11	0.1	0.03	0.22	0.8	3.4
14	SRE-6A	Ghoghriki	HP	21	7.2	991	634	267	390	29	3.7	115	25	326	62	53	19	0.06	0.23	0.8	2.6
15	SRE-6B	Ghoghriki	IM II	37	7.5	989	633	276	359	28	7.0	93	31	337	51	59	24	0.03	0.10	0.4	1.1
16	SRE-7A	Paragpur	HP	21	6.9	2865	1834	436	676	308	18	164	65	532	466	215	61	0.08	0.14	0.8	3.9
17	SRE-7B	Paragpur	IM II	37	7.4	1970	1261	238	477	229	12	112	48	290	428	130	5.3	0.04	0.36	0.4	2.2
18	SRE-8A	Hasanpur banaswa	HP	26	7.1	1150	736	302	335	72	7.1	83	31	368	78	21	72	0.06	ND	0.9	3.2
19	SRE-8B	Hasanpur banaswa	IM II	37	7.5	842	539	272	311	20	6.6	80	27	332	28	18	25	0.02	0.34	0.8	2.2
20	SRE-9A	Kapasa	HP	12	6.9	1654	1059	418	635	66	18	202	32	510	144	62	21	0.05	0.05	1.2	4.4
21	SRE-9B	Kapasa	IM II	37	7.7	632	404	232	185	41	3.6	41	20	283	8.0	4.5	0	0.02	0.42	0.7	3.1
22	SRE-10A	Tapri	HP	24	7.0	1186	759	392	470	31	4.1	86	62	478	28	46	20	0.08	0.13	1.1	3.9
23	SRE-10B	Tapri	IM II	37	7.2	956	612	322	342	33	6.4	68	42	393	42	23	2.2	0.04	0.31	0.5	3.2
24	SRE-10C	Tapri	TW	55	7.2	986	631	332	364	30	6.4	60	52	405	38	22	13	0.02	0.01	0.2	2.4
25	SRE-11A	Shekhpura kadim	HP	20	6.9	2866	1834	336	870	246	37	182	101	410	504	185	163	0.04	0.22	0.5	3.8
26	SRE-11B	Shekhpura kadim	IM II	37	7.8	524	335	186	201	14	4.5	36	27	227	8.0	15	1.3	0.03	0.24	0.1	1.2
27	SRE-12A	Lakhnour	HP	20	6.8	1866	1194	456	589	109	3.4	147	54	556	152	74	94	0.08	0.33	0.9	2.8
28	SRE-12B	Lakhnour	IM II	37	7.6	718	460	258	213	36	4.9	49	22	315	18	11	0	0.04	ND	0.4	1.1
29	SRE-12C	Lakhnour	TW	46	7.4	670	429	212	236	24	4.6	45	30	259	20	37	7.5	0.03	0.23	0.1	0.9
30	SRE-13A	Mubarakpur	HP	14	7.4	806	516	212	310	17	5.9	103	13	259	32	50	34	0.06	ND	1.0	4.5
31	SRE-13B	Mubarakpur	IM II	37	7.7	704	451	252	270	18	5.3	52	34	307	8.0	22	0	0.04	0.34	0.6	2.8
32	SRE-14A	Nandi	HP	24	7.0	1132	724	368	359	49	6.8	96	29	449	48	9.0	34	0.08	ND	1.2	2.8
33	SRE-14B	Nandi	IM II	37	7.5	989	633	366	372	30	7.6	70	48	447	14	15	0	0.02	ND	0.4	1.1
34	SRE-15A	Baleda Junardar	HP	24	7.5	788	504	256	304	26	3.4	56	40	312	36	25	0	0.06	0.24	0.8	2.6
35	SRE-15B	Baleda Junardar	IM II	37	7.7	658	421	226	243	23	4.5	48	30	276	26	9.0	0	0.04	0.26	0.2	0.9
36	SRE-16A	Rasoolpur kheri	HP	21	7.2	980	627	332	358	35	7.2	84	36	405	44	10	2.8	0.09	ND	0.6	3.2
37	SRE-16B	Rasoolpur kheri	IM II	37	7.7	570	365	202	194	18	4.3	53	15	246	16	6.0	3.6	0.07	0.04	0.2	2.4
38	SRE-17A	Jainpur	HP	21	7.2	1226	785	407	448	42	7.7	122	35	497	44	6.0	28	0.06	0.15	0.6	3.4
39	SRE-17B	Jainpur	IM II	37	7.6	882	564	334	321	27	5.3	76	32	407	4.0	9.0	1.6	0.02	0.12	0.2	0.9
40	SRE-18A	Sadhauli Hariya	HP	31	6.8	1076	689	301	387	30	3.3	114	25	367	32	85	26	0.06	0.28	0.9	2.2
41	SRE-18B	Sadhauli Hariya	IM II	37	7.7	695	445	252	245	19	5.2	52	28	307	10	18	1.6	0.04	0.56	0.3	1.2
42	SRE-19A	Tanshipur	HP	37	7.1	1502	961	418	422	106	11	108	37	510	156	25	2.0	0.11	0.09	0.8	2.6
43	SRE-19B	Tanshipur	IM II	37	7.2	1078	690	302	326	66	8.6	78	32	368	112	18	1.9	0.05	0.04	0.4	1.6
44	SRE-19C	Tanshipur	TW	56	7.2	1263	808	338	444	63	6.5	97	49	412	120	55	0.2	0.04	ND	0.1	0.6
45	SRE-20A	Shitala Khera	HP	38	7.2	1044	668	338	387	22	5.9	76	48	412	22	23	56	0.12	0.15	1.2	3.8
46	SRE-20B	Shitala Khera	IM II	37	7.7	924	591	312	369	19.6	5.8	72	46	381	44	14	5.8	0.05	ND	0.8	2.6
47	SRE-20C	Shitala Khera	TW	46	7.9	782	500	242	292	23	5.7	56	37	295	50	31	0	0.02	0.18	0.2	0.5
48	SRE-21A	Maheshpur	HP	37	8.2	1066	682	306	408	33	6.2	81	50	373	72	33	30	0.04	0.21	1.1	3.2
49	SRE-21B	Maheshpur	IM II	37	7.9	958	613	304	328	41	6.8	69	38	371	72	12	0	0.02	0.12	0.6	2.4
50	SRE-21C	Maheshpur	TW	55	7.5	672	430	242	251	21	4.6	48	32	295	16	4.0	4.9	0.04	0.34	0.2	0.8
51	SRE-22A	Mahmoodpur	HP	37	7.4	647	414	242	240	18	4.8	40	34	295	8.0	4.0	7.2	0.06	0.02	0.8	2.2
52	SRE-22B	Mahmoodpur	IM II	61	7.6	644	412	238	251	16	4.5	48	32	290	16	4.0	0	0.04	0.4	0.2	0.5
53	SRE-23A	Bhataul	HP	24	7.2	1152	737	392	430	39	7.6	98	45	478	44	18	4.6	0.08	ND	0.8	2.7
54	SRE-23B	Bhataul	IM II	37	7.5	852	545	308	338	19	5.5	76	36	376	24	6.0	0.1	0.03	0.38	0.4	1.6
55	SRE-23C	Bhataul	BW	49	7.3	878	562	316	317	21	5.5	81	28	386	22	11	0	0.01	0.35	0.2	0.8
56	SRE-24A	Banhera Khas	HP	14	7.4	666	426	242	268	7.7	2.6	53	33	295	4.0	16	11	0.06	0.24	0.8	2.8
57	SRE-24B	Banhera Khas	IM II	37	7.6	610	390	221	237	8.3	4.3	49	28	270	8.0	15	4.3	0.03	0.28	0.3	0.8
58	SRE-25A	Chandpur Kayasth	HP	20	7.3	865	554	308	331	13	8.6	90	26	376	10	10	16	0.09	0.14	0.9	2.9
59	SRE-25B	Chandpur Kayasth	IM II	37	7.4	648	415	234	255	11	4.3	76	16	285	16	2.0	1.8	0.05	0.28	0.4	1.8
60	SRE-25C	Chandpur Kayasth	BW	34	7.5	596	381	220	227	11	4.3	68	14	268	12	1.0	0	0.02	0.38	0.6	2.1
61	SRE-26A	Palauli	HP	15	6.8	796	509	272	333	13	1.8	69	39	332	18	15	17	0.06	0.15	0.9	2.6
62	SRE-26B	Palauli	IM II	37	7.4	858	549	312	329	14	6.2	84	29	381	20	11	0	0.02	0.1	0.4	1.6
63	SRE-27A	Sanpla Khatri	HP	7	7.3	1860	1190	508	640	102	8.7	184	44	620	136	68	24	0.14	0.28	0.6	3.2
64	SRE-27B	Sanpla Khatri	IM II	37	7.4	798	511	304	313	16	5.6	58	41	371	8.0	10	0	0.06	0.58	0.2	0.9
65	SRE-27C	Sanpla Khatri	BW	34	7.1	775	496	302	314	12	2.5	60	40	368	4.0	2.5	1.9	0.05	0.19	0.1	0.6
66	SRE-28A	Matauli	HP	15	6.8	1640	1050	540	534	86	9.1	112	62	659	36	55	24	0.11	0.28	0.8	2.1
67	SRE-28B	Matauli	IM II	37	8.0	632	404	242	248	9.0	4.5	40	36	295	9.0	5.5	0.8	0.05	0.22	0.5	2.2
68	SRE-28C	Matauli	BW	46	7.6	622	398	224	242	14	4.5	54	26	273	12	12	0	0.04	0.29	0.2	1.1
		Minimum			6.8	524	335	186	185	7.7	1.8	36	13	227	4.0	1.0	0	0.01	ND	0.1	0.5
		Maximum			8.2	2866	1834	540	870	308	37	202	101	659	504	215	163	0.14	0.58	1.5	4.9
		Mean			7.4	984	630	302	344	41	6.2	79	36	369	55	27	13	0.05	0.24	0.6	2.4

Table 4.6 Bacteriological Data of Ground Water Samples of District Saharanpur (March 2013)

S.No.	Sample ID	Location	Source	Depth	Total Coliform	Fecal Coliform
				m	per 100 ml	per 100 ml
1	SRE-1A	Sarda Heri	HP	31	<3	<3
2	SRE-1B	Sarda Heri	IM II	37	<3	<3
3	SRE-1C	Sarda Heri	TW	137	<3	<3
4	SRE-2A	Ibrahimpur	HP	21	<3	<3
5	SRE-2B	Ibrahimpur	IM II	37	<3	<3
6	SRE-3A	Pali	HP	46	<3	<3
7	SRE-3B	Pali	IM II	37	<3	<3
8	SRE-3C	Pali	TW	56	<3	<3
9	SRE-4A	Gagalhedi	HP	18	<3	<3
10	SRE-4B	Gagalhedi	IM II	37	<3	<3
11	SRE-4C	Gagalhedi	TW	40	<3	<3
12	SRE-5A	Khazoori Akbarpur	HP	20	<3	<3
13	SRE-5B	Khazoori Akbarpur	IM II	37	<3	<3
14	SRE-6A	Ghoghriki	HP	21	240	<3
15	SRE-6B	Ghoghriki	IM II	37	<3	<3
16	SRE-7A	Paragpur	HP	21	240	9
17	SRE-7B	Paragpur	IM II	37	240	4
18	SRE-8A	Hasanpur banaswa	HP	26	<3	<3
19	SRE-8B	Hasanpur banaswa	IM II	37	<3	<3
20	SRE-9A	Kapasa	HP	12	<3	<3
21	SRE-9B	Kapasa	IM II	37	240	<3
22	SRE-10A	Tapri	HP	24	<3	<3
23	SRE-10B	Tapri	IM II	37	<3	<3
24	SRE-10C	Tapri	TW	55	<3	<3
25	SRE-11A	Shekhpura kadim	HP	20	<3	<3
26	SRE-11B	Shekhpura kadim	IM II	37	<3	<3
27	SRE-12A	Lakhnour	HP	20	<3	<3
28	SRE-12B	Lakhnour	IM II	37	<3	<3
29	SRE-12C	Lakhnour	TW	46	<3	<3
30	SRE-13A	Mubarakpur	HP	14	<3	<3
31	SRE-13B	Mubarakpur	IM II	37	<3	<3
32	SRE-14A	Nandi	HP	24	23	4
33	SRE-14B	Nandi	IM II	37	<3	<3
34	SRE-15A	Baleda Junardar	HP	24	<3	<3
35	SRE-15B	Baleda Junardar	IM II	37	<3	<3
36	SRE-16A	Rasoolpur kheri	HP	21	<3	<3
37	SRE-16B	Rasoolpur kheri	IM II	37	<3	<3
38	SRE-17A	Jainpur	HP	21	<3	<3
39	SRE-17B	Jainpur	IM II	37	<3	<3
40	SRE-18A	Sadhauli Hariya	HP	31	<3	<3
41	SRE-18B	Sadhauli Hariya	IM II	37	<3	<3
42	SRE-19A	Tanshipur	HP	37	<3	<3
43	SRE-19B	Tanshipur	IM II	37	<3	<3
44	SRE-19C	Tanshipur	TW	56	<3	<3
45	SRE-20A	Shitala Khera	HP	38	<3	<3
46	SRE-20B	Shitala Khera	IM II	37	<3	<3
47	SRE-20C	Shitala Khera	TW	46	<3	<3
48	SRE-21A	Maheshpur	HP	37	<3	<3
49	SRE-21B	Maheshpur	IM II	37	<3	<3
50	SRE-21C	Maheshpur	TW	55	<3	<3
51	SRE-22A	Mahmoodpur	HP	37	<3	<3
52	SRE-22B	Mahmoodpur	IM II	61	<3	<3
53	SRE-23A	Bhataul	HP	24	<3	<3
54	SRE-23B	Bhataul	IM II	37	<3	<3
55	SRE-23C	Bhataul	BW	49	<3	<3
56	SRE-24A	Banhera Khas	HP	14	<3	<3
57	SRE-24B	Banhera Khas	IM II	37	<3	<3
58	SRE-25A	Chandpur Kayasth	HP	20	4	<3
59	SRE-25B	Chandpur Kayasth	IM II	37	<3	<3
60	SRE-25C	Chandpur Kayasth	BW	34	<3	<3
61	SRE-26A	Palauli	HP	15	<3	<3
62	SRE-26B	Palauli	IM II	37	<3	<3
63	SRE-27A	Sanpla Khatri	HP	7	<3	<3
64	SRE-27B	Sanpla Khatri	IM II	37	<3	<3
65	SRE-27C	Sanpla Khatri	BW	34	<3	<3
66	SRE-28A	Matauli	HP	15	<3	<3
67	SRE-28B	Matauli	IM II	37	<3	<3
68	SRE-28C	Matauli	BW	46	<3	<3

Table 4.7 Trace Element Data of Ground Water Samples of District Saharanpur (March 2013)

S.No.	Sample ID	Location	Source	Depth	Fe	Mn	Cu	Ni	Cr	Pb	Cd	Zn	As
				m	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
1	SRE-1A	Sarda Heri	HP	31	1554	385	19	37	36	40	11	66	ND
2	SRE-1B	Sarda Heri	IM II	37	782	97	14	ND	22	20	5	124	ND
3	SRE-1C	Sarda Heri	TW	137	107	301	21	ND	13	20	2	562	ND
4	SRE-2A	Ibrahimpur	HP	21	7490	284	10	ND	31	90	3	57	ND
5	SRE-2B	Ibrahimpur	IM II	37	12760	466	32	38	11	10	3	1099	ND
6	SRE-3A	Pali	HP	46	288	357	4	11	32	20	5	72	ND
7	SRE-3B	Pali	IM II	37	2714	396	5	20	31	ND	1	128	ND
8	SRE-3C	Pali	TW	56	877	292	5	ND	46	ND	2	466	ND
9	SRE-4A	Gagalhedi	HP	18	1021	347	8	96	29	ND	6	68	ND
10	SRE-4B	Gagalhedi	IM II	37	1507	321	6	78	14	ND	7	363	ND
11	SRE-4C	Gagalhedi	TW	40	164	258	5	43	50	70	12	412	ND
12	SRE-5A	Khazoori Akbarpur	HP	20	719	256	6	2	83	20	5	78	ND
13	SRE-5B	Khazoori Akbarpur	IM II	37	1619	248	18	45	62	30	1	224	ND
14	SRE-6A	Ghoghriki	HP	21	1200	201	12	99	80	50	4	145	ND
15	SRE-6B	Ghoghriki	IM II	37	621	193	14	6	18	30	5	320	ND
16	SRE-7A	Paragpur	HP	21	1398	1519	44	53	42	80	11	95	ND
17	SRE-7B	Paragpur	IM II	37	20128	288	15	60	39	30	8	135	ND
18	SRE-8A	Hasanpur banaswa	HP	26	282	681	11	8	14	10	2	120	ND
19	SRE-8B	Hasanpur banaswa	IM II	37	217	294	10	17	11	ND	6	165	ND
20	SRE-9A	Kapasa	HP	12	1161	2274	51	116	11	60	9	142	ND
21	SRE-9B	Kapasa	IM II	37	1279	110	10	12	ND	ND	3	115	ND
22	SRE-10A	Tapri	HP	24	1916	6	952	99	20	40	11	1080	ND
23	SRE-10B	Tapri	IM II	37	824	156	11	43	6	ND	5	95	ND
24	SRE-10C	Tapri	TW	55	510	255	17	ND	16	60	9	136	ND
25	SRE-11A	Shekhpura kadim	HP	20	2184	17	21	94	55	100	13	992	ND
26	SRE-11B	Shekhpura kadim	IM II	37	11444	99	21	16	16	50	3	155	ND
27	SRE-12A	Lakhnour	HP	20	1002	189	22	44	23	80	15	926	ND
28	SRE-12B	Lakhnour	IM II	37	3149	203	21	29	ND	50	1	125	ND
29	SRE-12C	Lakhnour	TW	46	40	90	7	63	ND	90	6	155	ND
30	SRE-13A	Mubarakpur	HP	14	106	256	7	64	ND	110	15	158	ND
31	SRE-13B	Mubarakpur	IM II	37	602	206	5	11	24	90	2	175	ND
32	SRE-14A	Nandi	HP	24	251	678	9	ND	27	90	6	325	ND
33	SRE-14B	Nandi	IM II	37	505	106	7	40	17	70	3	290	ND
34	SRE-15A	Baleda Junardar	HP	24	1097	161	7	34	49	40	1	345	ND
35	SRE-15B	Baleda Junardar	IM II	37	345	62	12	ND	47	ND	4	295	ND
36	SRE-16A	Rasoolpur kheri	HP	21	14060	419	9	63	70	63	7	315	ND
37	SRE-16B	Rasoolpur kheri	IM II	37	1058	158	21	26	66	26	4	186	ND
38	SRE-17A	Jainpur	HP	21	1042	285	9	103	82	103	5	320	ND
39	SRE-17B	Jainpur	IM II	37	1552	147	23	38	4	38	6	177	ND
40	SRE-18A	Sadhauli Hariya	HP	31	342	28	42	70	24	70	3	785	ND
41	SRE-18B	Sadhauli Hariya	IM II	37	8562	320	15	53	ND	53	8	988	ND
42	SRE-19A	Tanshipur	HP	37	398	726	21	36	20	36	6	724	ND
43	SRE-19B	Tanshipur	IM II	37	6788	415	10	ND	ND	ND	3	705	ND
44	SRE-19C	Tanshipur	TW	56	81	275	11	52	35	52	9	245	ND
45	SRE-20A	Shitala Khera	HP	38	24188	352	8	74	53	74	14	740	ND
46	SRE-20B	Shitala Khera	IM II	37	12824	368	14	102	62	102	ND	724	ND
47	SRE-20C	Shitala Khera	TW	46	50	285	27	67	2	67	6	365	ND
48	SRE-21A	Maheshpur	HP	37	1204	141	9	77	4	77	6	122	ND
49	SRE-21B	Maheshpur	IM II	37	3004	312	13	68	17	68	5	124	ND
50	SRE-21C	Maheshpur	TW	55	42	79	8	47	35	47	11	224	ND
51	SRE-22A	Mahmoodpur	HP	37	6510	84	12	ND	24	ND	ND	85	ND
52	SRE-22B	Mahmoodpur	IM II	61	210	49	8	5	ND	5.0	ND	105	ND
53	SRE-23A	Bhataul	HP	24	1107	257	10	ND	35	ND	5	80	ND
54	SRE-23B	Bhataul	IM II	37	1117	198	11	43	27	43	ND	125	ND
55	SRE-23C	Bhataul	BW	49	126	220	10	51	37	51	6	115	ND
56	SRE-24A	Banhera Khas	HP	14	3296	288	33	35	47	35	3	95	ND
57	SRE-24B	Banhera Khas	IM II	37	809	974	9	ND	17	ND	3	105	ND
58	SRE-25A	Chandpur Kayasth	HP	20	380	116	10	38	27	38	7	42	ND
59	SRE-25B	Chandpur Kayasth	IM II	37	484	126	9	40	32	40	1	100	ND
60	SRE-25C	Chandpur Kayasth	BW	34	557	59	8	39	33	39	ND	564	ND
61	SRE-26A	Palauli	HP	15	2356	79	20	92	23	12	ND	65	ND
62	SRE-26B	Palauli	IM II	37	270	132	10	38	15	38	4	120	ND
63	SRE-27A	Sanpla Khatri	HP	7	779	143	17	39	29	39	10	95	ND
64	SRE-27B	Sanpla Khatri	IM II	37	1329	192	11	54	6	54	2	106	ND
65	SRE-27C	Sanpla Khatri	BW	34	2243	275	15	13	39	13	2	224	ND
66	SRE-28A	Matauli	HP	15	3856	130	17	81	34	81	5	72	ND
67	SRE-28B	Matauli	IM II	37	411	192	13	ND	19	ND	ND	110	ND
68	SRE-28C	Matauli	BW	46	57	100	16	56	22	20	4	156	ND
		Minimum			40	6	4	ND	ND	ND	ND	42	ND
		Maximum			24188	2274	952	116	83	110	15	1099	ND
		Mean			2691	294	28	50	31	52	5.7	284	ND

4.2.2 District Muzaffarnagar

Total 48 ground water samples from private hand pumps, IM II hand pumps and tube wells/bore wells were collected from 17 villages in the buffer zone of 2 km on the banks of Rivers Hindon and Kali falling in District Muzaffarnagar (Fig. 4.4) and the results (Tables 4.8 to 4.10) are discussed in the following sections.

General Characteristics

The pH values in the ground water samples collected from District Muzaffarnagar fall within the range of 6.8 to 7.9 in hand pumps, 7.1 to 8.0 in IM II hand pumps and 7.1 to 8.2 in tube wells/bore wells. The pH values for all of the samples are well within the limits prescribed by BIS (2012) for various uses of water including drinking and other domestic supplies.

The electrical conductivity and dissolved salt concentrations are directly related to the concentration of ionized substance in water and may also be related to problems of excessive hardness and/or other mineral contamination. The conductivity values in the ground water samples vary from 485 to 2520 μS/cm in hand pumps, 442 to 1300 μS/cm in IM II hand pumps and 492 to 1145 μS/cm in tube wells/bore wells. The conductivity above 1000 μS/cm was observed in 63%, 12% and 7% samples of hand pumps, IM II hand pumps and tube wells/bore wells respectively. The maximum conductivity value of 2520 μS/cm was observed in the hand pump of village Nagla Rai.

The TDS value in the ground water samples collected from the District Muzaffarnagar varies from 310 to 1613 mg/L in hand pumps, 283 to 832 mg/L in IM II hand pumps and 315 to 733 mg/L in tube wells/bore wells. TDS values above the acceptable limit of 500 mg/L were observed in 88%, 18% and 20% samples of hand pumps, IM II hand pumps and tube wells/bore wells respectively. Water containing more than 500 mg/L of TDS is not considered acceptable for drinking water supplies, though more highly mineralized water is also used where better water is not available. For this reason, 500 mg/L as the acceptable limit and 2000 mg/L as the maximum permissible limit has been suggested for drinking water (BIS, 2012). None of the collected samples from District Muzaffarnagar exceeded the permissible limit of 2000 mg/L. Water containing TDS more than 500 mg/L causes gastrointestinal irritation.

Alkalinity in natural water is mainly due to presence of carbonates, bicarbonates and hydroxides. Bicarbonates represent the major form since they are formed in considerable amount from the action of carbonates upon the basic materials in the soil. The alkalinity value in the collected samples from district Muzaffarnagar varies from 156 to 463 mg/L in hand pumps, 144 to 402 mg/L in IM II hand pumps and 172 to 324 mg/L in tube wells/bore wells. About 94% of the samples collected from hand pumps, 77% from IM II hand pumps and 80% from tube wells/bore wells exceeded the acceptable limit of 200 mg/L but within the maximum permissible limit of 600 mg/L.

Hardness of water is due to carbonates, sulphates and chlorides of calcium and magnesium. A limit of 200 mg/L as acceptable limit and 600 mg/L as permissible limit has been recommended for drinking water (BIS, 2012). The total hardness values in the samples collected

from district Muzaffarnagar range from 195 to 634 mg/L in hand pumps, 179 to 495 mg/L in IM II hand pumps and 170 to 481 mg/L in tube wells/bore wells. The ground water samples from hand pumps of Nagla Rai, Ladwa and Rampur crossed the permissible limit of 600 mg/L.

In ground water of the samples collected from District Muzaffarnagar, the values of calcium range from 37 to 167 mg/L in hand pumps, 32 to 162 mg/L in IM II hand pumps and 32 to 145 mg/L in tube wells/bore wells and the values of magnesium range from 25 to 62 mg/L in hand pumps, 21 to 42 mg/L in IM II hand pumps and 19 to 45 mg/L in tube wells/bore wells. The acceptable limit for calcium and magnesium for drinking water are 75 and 30 mg/L respectively (BIS, 2012). In ground water, the calcium content generally exceeds the magnesium content in accordance with their relative abundance in rocks. All ground water samples collected from District Muzaffarnagar fall within the maximum permissible limit of 200 mg/L of calcium and 100 mg/L of magnesium.

The concentration of sodium in the the samples collected from District Muzaffarnagar varies from 6.2 to 160 mg/L in hand pumps, 4.5 to 104 mg/L in IM II hand pumps and 8.4 to 53 mg/L in tube wells/bore wells. The Bureau of Indian Standards has not included sodium in drinking water standards. The high sodium values in the collected samples may be attributed to base-exchange phenomena and causes sodium hazard. Ground water with such high sodium is not suitable for irrigation purpose.

Potassium is an essential element for humans, plants and animals and derived in food chain mainly from vegetation and soil. The main sources of potassium in ground water include rain water, weathering of potash silicate minerals, use of potash fertilizers and use of surface water for irrigation. The concentration of potassium in the ground water samples collected from District Muzaffarnagar varies from 2.2 to 126 mg/L in hand pumps, 3.5 to 42 mg/L in IM II hand pumps and 3.3 to 7.0 mg/L in tube wells/bore wells. The Bureau of Indian Standards has not included potassium in drinking water standards. However, the European Economic Community has prescribed guideline level of potassium at 10 mg/L in drinking water. As per EEC criteria, ground water samples from hand pump of Nagla Rai, Hadoli and Chandsina and IM II hand pumps of village Ladwa exceeded the guideline level of 10 mg/L.

The concentration of chloride in the samples collected from District Muzaffarnagar varies from 4.0 to 204 mg/L in hand pumps, 4.0 to 98 mg/L in IM II hand pumps and 4.0 to 62 mg/L in tube wells/bore wells. All samples were observed within the acceptable limit of 250 mg/L. The limits of chloride have been laid down primarily from taste considerations. A limit of 250 mg/L chloride has been recommended as acceptable limit and 1000 mg/L as the permissible limit for drinking water (BIS, 2012). However, no adverse health effects on humans have been reported from intake of waters containing even higher content of chloride. The concentration of sulphate in the samples collected from District Muzaffarnagar varies from 8.0 to 98 mg/L in hand pumps, 1.0 to 45 mg/L in IM II hand pumps and 5.5 to 48 mg/L in tube wells/bore wells. Bureau of Indian standard has prescribed 200 mg/L as the acceptable limit and 400 mg/L as the permissible limit for sulphate in drinking water. In the samples collected from District Muzaffarnagar, none of the samples exceeded the maximum acceptable limit of 200 mg/L.

Nitrate content in drinking water is considered important for its adverse health effects and moderately toxicity. A limit of 45 mg/L has been prescribed by BIS (2012) for drinking water supplies. Its concentration above 45 mg/L may prove detriment to human health. In higher concentrations, nitrate may produce a disease known as methaemoglobinaemia (blue babies) which generally affects bottle-fed infants. Repeated heavy doses of nitrates on ingestion may also cause carcinogenic diseases. The nitrate content in the samples collected from District Muzaffarnagar varies from 2.4 to 282 mg/L in hand pumps, 0 to 74 mg/L in IM II hand pumps and 0 to 46 mg/L in tube wells/bore wells. The nitrate concentration was observed more than permissible limit of 45 mg/L in ground water samples from hand pump and IM II hand pumps of Purbaliyan, hand pump and tube well of village Nagla Rai, hand pumps of villages Jeewna, Didaheri, Hadoli and Rampur, which may be attributed to contamination by industrial/domestic waste disposal.

The presence of fluoride in ground water may be attributed to the localized effects of natural sources. The fluoride is present in soil strata due to the presence of geological formations like fluorspar, fluorapatite, ampheboles such as hornblinde, trimolite and mica. Weathering of alkali, silicate, igneous and sedimentary rocks specially shales contribute a major portion of fluorides to ground waters. In addition to natural sources, considerable amount of fluorides may be contributed due to man’s activities. Fluoride salts are commonly used in steel, aluminium, bricks and tile-industries. The fluoride containing insecticides and herbicides may be contributed through agricultural runoff. Phosphatic fertilizers, which are extensively used, often contain fluorides as impurity and these may increase levels of fluoride in soil. The accumulation of fluoride in soil eventually results in its leaching due to percolating water, thus increase fluoride concentration in ground water. The fluoride content in the ground water samples collected from District Muzaffarnagar varies from 0.07 to 0.77 mg/L in hand pumps, 0.10 to 0.76 mg/L in IM II hand pumps and 0.13 to 0.92 mg/L in tube wells/bore wells. Ground water samples collected from all villages of the District Muzaffarnagar fall within the acceptable limit of 1.0 mg/L.

From the above discussion, it is clearly indicated that in the ground water samples collected from District Muzaffarnagar, the concentration of total dissolved solids was observed above the acceptable limit of 500 mg/L in more than 88%, 18% and 20% samples of hand pumps, IM II hand pumps and tube wells/bore wells respectively but none of the samples exceeded the maximum permissible limit of 2000 mg/L. The hardness values also observed to exceed the permissible limit in ground water samples from the hand pumps of villages Nagla Rai, Ladwa and Rampur. The concentration of nitrate exceeded the permissible limit in ground water samples collected from the hand pump and IM II hand pumps of Purbaliyan, hand pump and tube well of village Nagla Rai, hand pumps of villages Jeewna, Didaheri, Hadoli and Rampur. The concentration of fluoride was observed within the acceptable limit in all the collected samples. The violation of BIS limit could not be ascertained for sodium and potassium as no permissible limit for these constituents has been prescribed in BIS drinking water specifications. On the basis of above results, it can be inferred that ground water from hand pumps have the problem of TDS, hardness and nitrate specially in the area of Nagla Rai and Rampur, which may be attributed to possible impact of effluents discharged into River Hindon and River Kali on the ground water.

Bacteriological Parameters

In water quality control technology, the principal indicator of suitability of water for domestic, industrial or other uses is the coliform group of bacteria. The density of coliform group is the criteria for the extent of contamination and has been the basis for bacteriological water quality standard. Further, the presence of faecal colifirms in water is the indicator of a potential public health problem, because faecal matter is a source of pathogenic bacteria and viruses. The faecal coliform bacteria contaminate water through percolation from contamination sources (domestic sewage and septic tank) and also because of poor sanitary system. The indiscriminate land disposal of domestic waste on surface and improper disposal of solid waste further aggravate the problem of bacterial contamination in water. The collected samples from District Muzaffarnagar were analysed for bacteriological parameters viz; Total Coliform and Faecal Coliform. The result of bacteriological analysis is given in Table 4.9. The result shows that the bacterial contamination was observed in sixteen ground water samples of nine villages of the District Muzaffarnagar.

Heavy Metals

Heavy metals in ground water have a considerable significance due to their toxicity and adsorption behaviour. Heavy metals are not biodegradable and enter the food chain through a number of pathways causing progressive toxicity due to the accumulation in human and animal organs during their life span on long term exposure to contaminated environments. Despite the presence of trace concentrations of Cr, Mn, Co, Cu and Zn in the aquatic environment, which is essential to a number of life processes, high concentrations of these metals become toxic. The major sources of heavy metals in ground water include weathering of rock minerals, discharge of sewage and other waste effluents on land and runoff water. The trace element data of ground water samples collected from the District Muzaffarnagar is given in Table 4.10. The distribution of different metals is shown graphically in Fig. 4.5. The toxic effects of these elements and extent of their contamination in ground water is discussed in the following sections.

Iron (Fe): The concentration of iron in the ground water samples collected from District Muzaffarnagar ranges from 0.044 to 4.772 mg/L in hand pumps, 0.144 to 4.225 mg/L in IM II hand pumps and 0.012 to 0.351 mg/L in tube wells/bore wells. The Bureau of Indian Standards has recommended 0.3 mg/L as the acceptable limit for iron in drinking water (BIS, 2012). WHO has prescribed 0.3 mg/L as the acceptability threshold value for iron (WHO, 2011). It is evident from the results that 81% samples of hand pumps, 94% samples of IM II hand pumps and about 7% of tube wells/bore wells exceed the acceptable limit of 0.3 mg/L. High concentration of iron was observed in the ground water of Sujru, Lachhera, Purbaliyan, Jeewna, Kilasa, Didaheri, Kasoli, Nagla Rai, Atali, Hadoli, Titawi, Inchauli, Rampur, Chandsina and Budhana Khadar. The higher concentration of iron in the ground water after Atali may be attributed to leaching of industrial wastes from river Kali, which meets river Hindon at Atali.

It is a known fact that iron in trace amounts is essential for nutrition. High concentrations of iron generally cause inky flavour, bitter and astringent taste to water. Well water containing soluble iron remain clear while pumped out, but exposure to air causes precipitation of iron due to oxidation, with a consequence of rusty colour and turbidity. The objection to iron in the distribution system is not due to health reason but to staining of laundry and plumbing fixtures and appearance. Taste and order problems may be caused by filamentous organism that prey on iron compounds (frenothrix, gallionella and leptothrix are called iron bacteria), originating another consumer's objection (red water). The presence of iron bacteria may clog well screens or develop in the distribution system, particularly when sulphate compounds in addition to iron may be subjected to chemical reduction.

Manganese (Mn): The concentration of manganese in the ground water samples collected from District Muzaffarnagar ranges from 0.003 to 0.931 mg/L in hand pumps, 0.005 to 0.460 mg/L in IM II hand pumps and 0.008 to 0.113 mg/L in tube wells/bore wells. Manganese is an essential trace nutrient for plants and animals, which does not occur naturally as a metal but is found in various salts and minerals frequently in association with iron compounds. Manganese may gain entry into the body by inhalation, consumption of food and through drinking water. A concentration of 0.1 mg/L has been recommended as an acceptable limit and 0.3 mg/L as the permissible limit for drinking water (BIS, 2012). WHO has prescribed 0.1 mg/L as the acceptability threshold value and 0.4 mg/L as health based value (WHO, 2011). It is evident from the results that about 45% of the samples collected each from the hand pumps and IM II hand pumps and about 87% samples from tube wells/bore wells fall within the acceptable limit of 0.1 mg/L and about 19% samples from hand pumps and 6% samples from IM II hand pumps exceeds the maximum permissible limit of 0.3 mg/L. The presence of manganese above permissible limit of drinking water often imparts alien taste to water. It also has adverse effects on domestic uses and water supply structures.

Copper (Cu): The concentration of copper in the ground water samples collected from District Muzaffarnagar ranges from 0.011 to 0.290 mg/L in hand pumps, 0.008 to 0.028 mg/L in IM II hand pumps and 0.006 to 0.019 mg/L in tube wells/bore wells. The Bureau of Indian Standards has recommended 0.05 mg/L as the acceptable limit and 1.5 mg/L as the permissible limit in the absence of alternate source (BIS, 2012). Beyond 0.05 mg/L the water imparts astringent taste and cause discoloration and corrosion of pipes, fittings and utensils. World Health Organization has recommended 2.0 mg/L as the provisional guideline value for drinking purpose (WHO, 2011). In the present investigation, two samples collected from hand pumps of District Muzaffarnagar exceed the acceptable limit of 0.05 mg/L.

Nickel (Ni): The concentration of nickel in the ground water samples collected from District Muzaffarnagar ranges from ND to 0.072 mg/L in hand pumps, ND to 0.070 mg/L in IM II hand pumps and ND to 0.041 mg/L in tube wells/bore wells. The Bureau of Indian Standards has recommended 0.02 mg/L as the acceptable limit (BIS, 2012). World Health Organization has recommended 0.07 mg/L as the guideline value for drinking purposes (WHO, 2011). In this range it is not harmful in drinking water. About 62%, 47% and 53% of samples each from hand pumps, IM II hand pumps and bore wells/tube wells exceed the BIS limit of 0.02 mg/L.

Chromium (Cr): The concentration of chromium in the ground water samples collected from District Muzaffarnagar ranges from ND to 0.026 mg/L in hand pumps, ND to 0.028 mg/L in IM II hand pumps and ND to 0.017 mg/L in tube wells/bore wells. A concentration of 0.05 mg/L has been recommended as an acceptable limit for drinking water (BIS, 2012). WHO has also prescribed 0.05 mg/L as the guideline value for drinking water (WHO, 2011). None of the samples exceeds the BIS limit of 0.05 mg/L.

Hexavalent chromium has a deleterious effect on the liver, kidney, and respiratory organs with hemorrhagic effects, dermatitis, and ulceration of the skin for chronic and subchronic exposure. Municipal wastewater release considerable amount of chromium into the environment. In the natural environment, Cr(+6) is likely to be reduced to Cr(+3), thereby reducing the toxic impact of chromium discharges. The pathways of chromium contribution to ground water are that the chromium containing industrial effluent discharged into stream, the hexavalent state chromium may be reduced to trivalent state and later adsorbed on the suspended particulate. In case, it could not be adsorbed, the chromium remain in the form of colloidal suspension, may precipitate and become part of stream sediment, from where it may reach to ground water through percolation containing shallow aquifers.

Lead (Pb): In the ground water samples collected from District Muzaffarnagar, the concentration of lead ranges from ND to 0.115 mg/L in hand pumps, ND to 0.123 mg/L in IM II hand pumps and ND to 0.084 mg/L in tube wells/bore wells. The Bureau of Indian Standards has prescribed 0.01 mg/L lead as the desirable limit for drinking water (BIS, 2012). Beyond this limit, the water becomes toxic. WHO has also prescribed 0.01 mg/L as guideline value for drinking water (WHO, 2011). About 94%, 65% and 73% of samples each from hand pumps, IM II and bore wells/tube wells exceed the BIS limit of 0.01 mg/L.

Lead is not considered an essential nutritional element and is a cumulative poison to humans. Acute lead poisoning is extremely rare. The typical symptoms of advanced lead poisoning are constipation, anemia, gastrointestinal disturbance, tenderness and gradual paralysis in muscles, specifically arms with possible cases of lethargy and moroseness. The major source of lead contamination is the combustion of fossil fuel. Lead is removed from the atmosphere by rain and falls back on the earth surface and seeps into the ground. Lead passes from the soil to water and to the plants and finally into the food chain. In drinking water it occurs primarily due to corrosion of lead pipes and solders, especially in areas of soft water. It may be noted that the use of soft water of slightly acidic pH and the use of lead pipes in service and domestic water lines may provide higher concentrations of lead at the consumers's tap, particularly when the water use is minimal in the household (overnight still water in pipes).

Cadmium (Cd): In the ground water samples collected from District Muzaffarnagar, the concentration of cadmium ranges from ND to 0.013 mg/L in hand pumps, ND to 0.057 mg/L in IM II hand pumps and ND to 0.012 mg/L in tube wells/bore wells. The Bureau of Indian Standards has prescribed 0.003 mg/L cadmium as the acceptable limit for drinking water (BIS, 2012). Beyond this limit, the water becomes toxic. WHO has also prescribed 0.003 mg/L cadmium as the guideline value for drinking water (WHO, 2011). The drinking water having more than 3 μg/L of cadmium can cause bronchitis, emphysema, anaemia and renal stone formation in animals. About 63% samples from hand pumps and 47% samples each from IM II hand pumps and tube wells/bore wells exceed the BIS limit of 0.003 mg/L.

Zinc (Zn): The concentration of zinc in the ground water samples collected from District Muzaffarnagar ranges from 0.016 to 0.189 mg/L in hand pumps, 0.047 to 0.148 mg/L in IM II hand pumps and 0.019 to 0.134 mg/L in tube wells/bore wells. The Bureau of Indian Standards has prescribed 5.0 mg/L zinc as the acceptable limit and 15 mg/L as the permissible limit for drinking water (BIS, 2012). WHO has prescribed 3.0 mg/L as the guideline value for drinking water (WHO, 2011). All the samples were found within the desirable limit prescribed by BIS (2012) and WHO (2011).

Arsenic (As): In the ground water samples collected from District Muzaffarnagar, the concentration of arsenic was not detected. Ground water is expected to contain higher arsenic concentrations than surface water. Because of its presence in geological materials, arsenic can be traced in water as originated by natural processes or by industrial activities – industrial waste, arsenical pesticides and smelting operations. Generally, arsenic found in two state – As(III) and As(V) in ground water. As(III) compounds are more toxic than As(V) compounds. Arsenic compounds are skin and lung carcinogens in humans. The Bureau of Indian Standards has prescribed 0.01 mg/L arsenic as the acceptable limit and 0.05 mg/L as the permissible limit for drinking water (BIS, 2012). Beyond this limit, the water becomes toxic. WHO has prescribed 0.01 mg/L arsenic as the guideline value for drinking water (WHO, 2011). In the present investigation, all the ground water samples collected from District Muzaffarnagar were found within the acceptable limit prescribed by BIS (2012).

From the above results, it is quite clear that the presence of heavy metals has been recorded in many location and the water quality standards have been violated for iron (13 samples from hand pumps, 16 samples from IM II hand pumps and 1 sample from tube well), manganese (3 samples from hand pumps and 1 sample from IM II), copper (2 samples from hand pumps), nickel (10 samples from hand pumps, 8 samples each from IM II hand pumps and tube wells/bore wells), lead (15 samples from hand pumps, 11 samples each from IM II hand pumps and tube wells/bore wells), Cadmium (10 samples from hand pumps, 8 samples from IM II hand pumps and 7 samples from tube wells/bore wells) out of collected 16 samples from hand pumps, 17 samples from IM II hand pumps and 15 samples from tube wells/bore wells of District Muzaffarnagar.

Pesticides

The analysis of nine organo-chlorinated pesticides (Aldrin, α-BHC, β-BHC, γ-BHC, δ-BHC, DDD, DDE, Endosulphan and Methoxychlor) was carried out in ground water samples from IM II hand pump of Purbaliyan and Titawi of District Muzaffarnagar. Out of the nine chlorinated pesticides analysed, only one pesticide γ-BHC has been detected in the ground water of Purbaliyan (6.345 μg/L) and Titawi (5.559 μg/L). The concentration of γ-BHC pesticide exceeds the permissible limit in both ground water samples. The presence of γ-BHC in ground water may be attributed due to their use in agricultural activities and for vector control programmes. The pesticide applied on surface might have leached through soil strata under the influence of hydraulic gradient and become source of contamination in ground water.

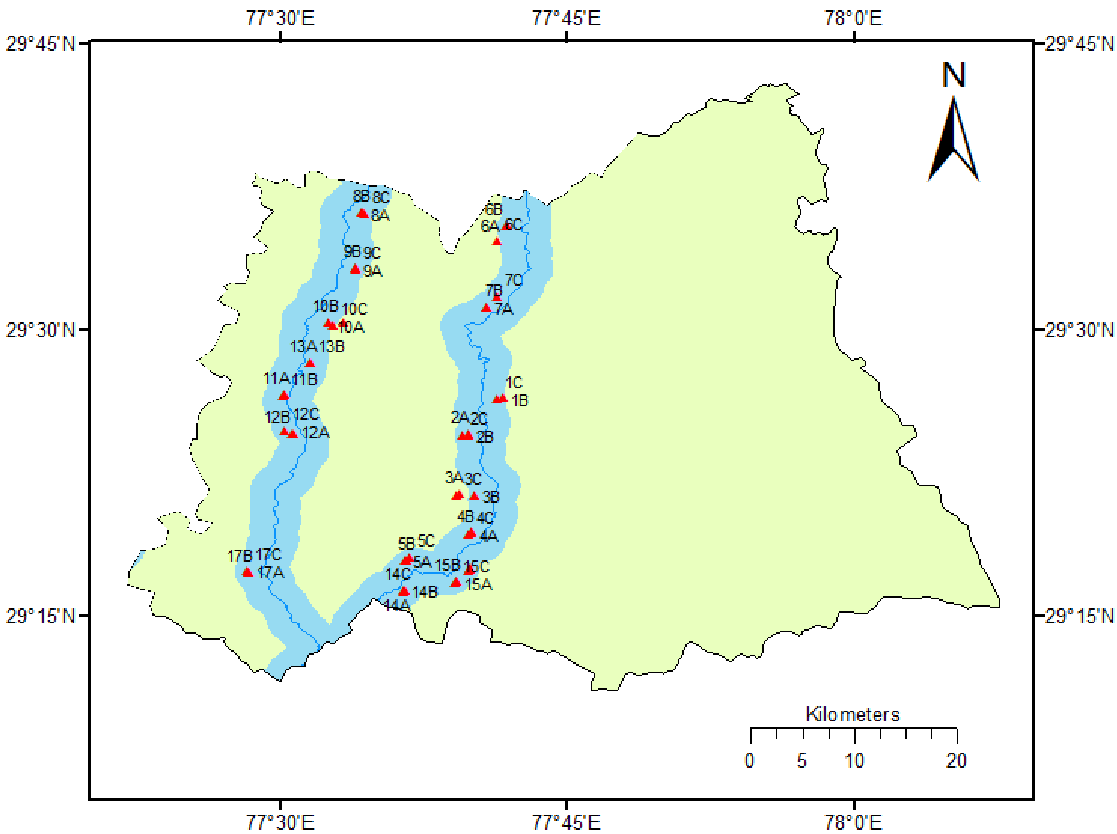


Fig. 4.4 Ground Water Sampling Locations in District Muzaffarnagar in Two km Buffer Zone of River Hindon and Kali

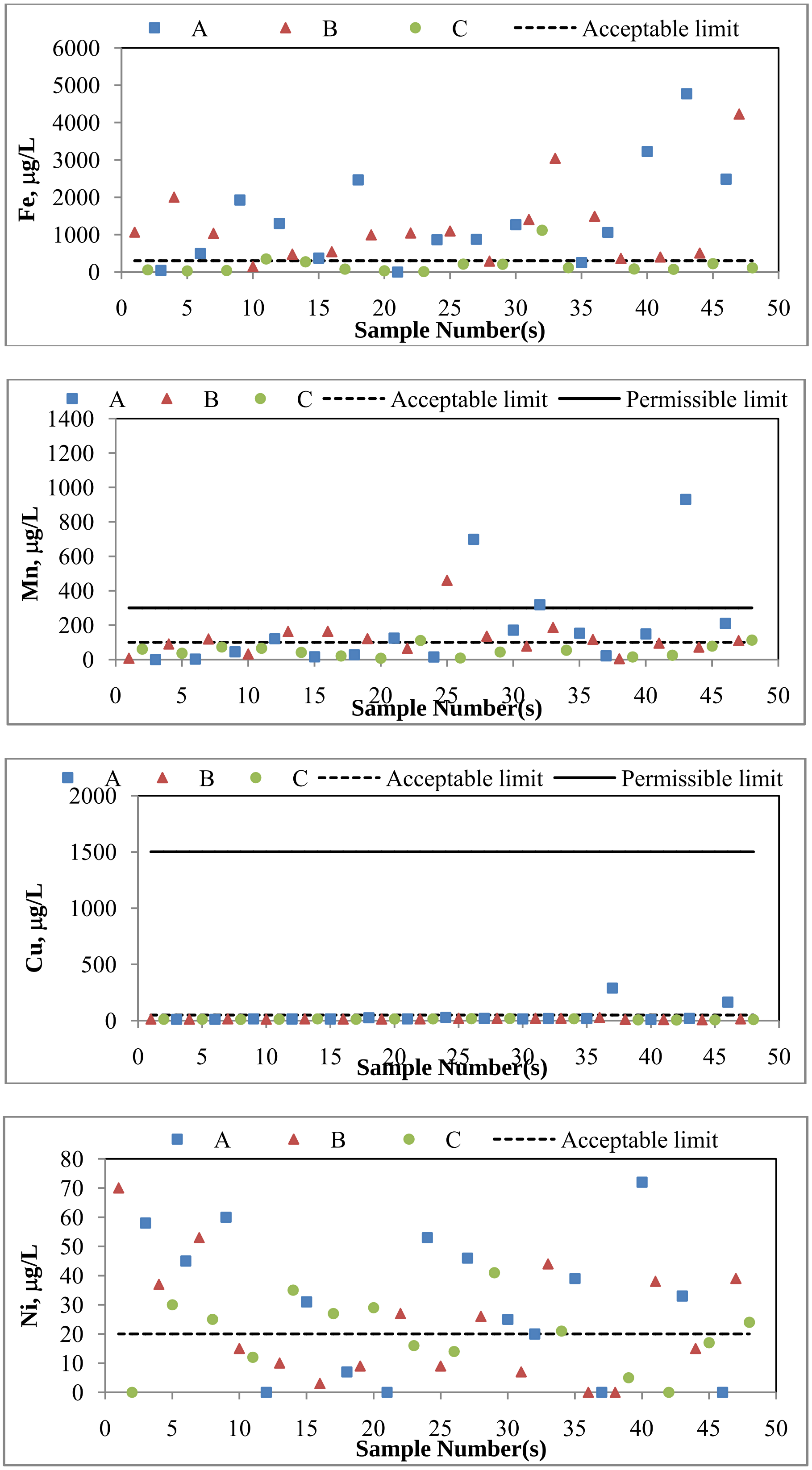


Fig. 4.5 Distribution of Trace Elements in Ground Water of District Muzaffarnagar

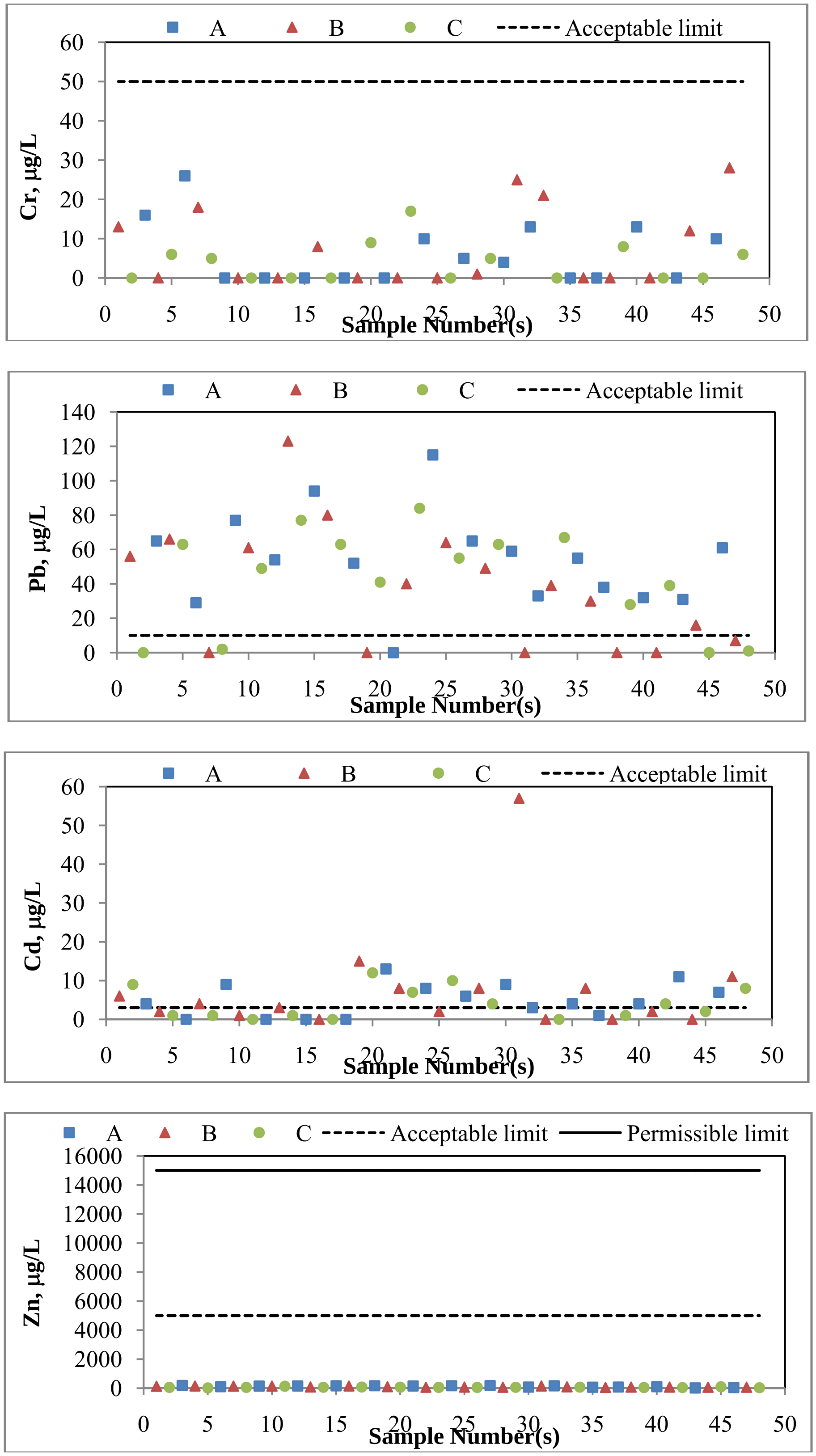


Fig. 4.5 (Contd.) Distribution of Trace Elements in Ground Water of District Muzaffarnagar

Table 4.8 Hydro-chemical Data of Ground Water Samples of District Muzaffarnagar (March 2013)

S.No.	Sample ID	Location	Source	Depth	pH	EC	TDS	Alk	Hard	Na	K	Ca	Mg	HCO3	Cl	SO4	NO3	PO4	F	BOD	COD
				m		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1	MZN-1B	Sujru	IM II	12	7.3	670	429	212	282	21	4.2	72	25	259	8.0	22	14	0.06	0.13	0.8	3.4
2	MZN-1C	Sujru	TW	30	7.7	498	319	174	212	15	4.1	37	29	212	6.0	12	2.1	0.04	0.43	0.6	3.2
3	MZN-2A	Lachhera	HP	21	7.1	974	623	302	384	32	6.3	103	31	368	12	29	39	0.09	0.26	0.4	1.5
4	MZN-2B	Lachhera	IM II	37	7.4	552	353	204	203	19	4.7	32	30	249	8.0	8.0	0	0.04	0.35	0.2	0.8
5	MZN-2C	Lachhera	TW	38	7.6	537	344	201	204	16	3.9	34	29	245	4.0	8.0	1.0	0.04	0.24	0.1	0.4
6	MZN-3A	Purbaliyan	HP	11	7.2	934	598	224	402	6.2	2.8	120	25	273	32	48	88	0.09	0.30	1.1	4.6
7	MZN-3B	Purbaliyan	IM II	46	7.1	1300	832	302	495	52	8.0	162	22	368	98	45	74	0.04	0.10	0.8	3.2
8	MZN-3C	Purbaliyan	TW	67	7.7	492	315	172	204	13	3.6	34	29	210	8.0	17	0	0.03	0.50	0.2	0.8
9	MZN-4A	Jeewna	HP	14	7.0	1481	948	338	528	42	8.8	167	27	412	78	43	166	0.08	0.13	1.8	5.9
10	MZN-4B	Jeewna	IM II	46	7.5	576	369	212	220	21	5.0	47	25	259	4.0	5.5	0	0.02	0.48	0.9	3.1
11	MZN-4C	Jeewna	TW	24	7.5	516	330	180	203	18	4.1	50	19	220	8.0	5.5	4.0	0.01	0.26	0.2	0.8
12	MZN-5A	Kilasa (Kitas)	HP	17	7.2	998	639	330	323	52	5.7	67	38	403	20	21	29	0.06	0.42	1.2	3.5
13	MZN-5B	Kilasa (Kitas)	IM II	76	7.4	665	426	234	300	17	3.9	64	34	285	7.0	13	0	0.03	0.50	0.8	3.0
14	MZN-5C	Kilasa (Kitas)	TW	61	7.8	900	576	324	385	29	4.9	80	45	395	8.0	9.5	1.8	0.02	0.40	0.4	2.6
15	MZN-6A	Rohana Khurd	HP	14	7.1	870	557	286	399	10	2.2	112	29	349	8.0	33	9.0	0.12	ND	0.9	2.6
16	MZN-6B	Rohana Khurd	IM II	37	7.6	583	373	202	264	4.5	4.3	58	29	246	4.0	23	0.3	0.08	0.38	0.4	1.2
17	MZN-6C	Rohana Khurd	TW	38	7.2	632	404	211	280	8.4	3.9	71	25	257	8.0	18	10	0.04	0.24	0.3	0.5
18	MZN-7A	Didaheri	HP	18	7.6	1202	769	306	518	29	2.9	145	38	373	90	33	55	0.06	ND	0.9	3.4
19	MZN-7B	Didaheri	IM II	34	7.6	552	353	202	219	15	3.9	50	23	246	8.0	1.0	4.0	0.01	0.25	0.6	2.4
20	MZN-7C	Didaheri	TW	32	7.3	642	411	208	240	20	3.3	55	25	254	12	16	24	0.01	0.16	0.4	1.6
21	MZN-8A	Kasoli	HP	24	7.6	772	494	250	306	14	5.2	70	32	305	4.0	26	36	0.08	0.11	1.7	3.6
22	MZN-8B	Kasoli	IM II	55	7.6	498	319	184	191	16	3.6	32	27	224	8.0	4.5	0	0.02	0.37	1.1	2.8
23	MZN-8C	Kasoli	TW	38	7.4	722	462	240	305	19	4.3	63	36	293	10	22	12	0.04	0.18	0.9	3.0
24	MZN-9A	Nagla Rai	HP	6	7.7	2520	1613	463	629	160	87	150	62	565	204	98	282	0.14	0.07	1.2	2.8
25	MZN-9B	Nagla Rai	IM II	38	7.7	652	417	204	281	16	5.0	50	38	249	10	33	15	0.04	0.2	0.4	1.6
26	MZN-9C	Nagla Rai	TW	38	7.2	784	502	212	333	16	5.2	61	44	259	20	48	46	0.03	0.16	0.3	0.8
27	MZN-10A	Ladwa	HP	9	6.8	1688	1080	438	622	97	6.5	152	59	534	160	50	16	0.12	0.28	0.9	3.6
28	MZN-10B	Ladwa	IM II	49	7.5	780	499	210	289	15	42	50	40	256	36	33	24	0.04	0.47	0.3	2.2
29	MZN-10C	Ladwa	TW	27	7.1	1145	733	309	481	33	6.7	145	29	377	62	45	31	0.06	0.25	0.2	0.9
30	MZN-11A	Atali	HP	14	7.2	1050	672	302	365	57	7.5	72	45	368	74	31	16	0.06	0.42	0.9	2.9
31	MZN-11B	Atali	IM II	24	7.3	888	568	260	340	37	6.0	67	42	317	40	12	44	0.04	0.66	0.6	2.2
32	MZN-12A	Hadoli	HP	15	7.9	1412	904	403	410	91	11	72	56	492	72	54	51	0.07	0.35	1.6	4.4
33	MZN-12B	Hadoli	IM II	40	7.2	1266	810	402	377	104	7.0	85	40	490	48	30	1.2	0.02	0.28	0.4	1.4
34	MZN-12C	Hadoli	TW	46	7.6	572	366	202	170	42	4.6	32	22	246	8.0	8.5	0	0.01	0.92	0.1	0.4
35	MZN-13A	Titawi	HP	17	7.1	1015	650	324	301	62	6.7	73	29	395	30	18	32	0.08	0.11	0.8	2.6
36	MZN-13B	Titawi	IM II	46	7.5	698	447	244	296	18	4.6	56	38	298	12	5.0	12	0.02	0.25	0.4	1.2
37	MZN-14A	Inchauli	HP	21	7.9	485	310	156	195	11	3.3	37	25	190	8.0	8.0	23	0.07	0.41	0.9	3.2
38	MZN-14B	Inchauli	IM II	55	7.9	442	283	144	179	11	3.5	34	23	176	4.0	14	15	0.02	0.29	0.6	1.9
39	MZN-14C	Inchauli	TW	21	7.6	699	447	230	286	19	4.3	62	32	281	10	10	28	0.04	0.13	0.2	0.4
40	MZN-15A	Rampur	HP	18	7.0	1598	1023	305	634	43	6.7	160	57	372	130	85	168	0.06	0.27	0.8	2.6
41	MZN-15B	Rampur	IM II	46	7.8	550	352	162	236	15	4.2	42	32	198	12	35	11	0.04	0.23	0.4	1.2
42	MZN-15C	Rampur	TW	61	7.4	686	439	214	279	18	5.8	64	29	261	16	21	21	0.02	0.36	0.2	0.9
43	MZN-16A	Chandsina	HP	17	7.1	1708	1093	422	452	107	126	112	42	515	172	12	2.4	0.05	0.62	0.6	1.6
44	MZN-16B	Chandsina	IM II	46	8.0	572	366	192	245	15	4.3	42	34	234	14	18	2.9	0.04	0.38	0.3	0.6
45	MZN-16C	Chandsina	TW	61	7.8	591	378	202	261	14	4.4	52	32	246	4.0	19	3.3	0.02	0.50	0.1	0.4
46	MZN-17A	Budhana Khadar	HP	31	7.5	1005	643	288	380	52	6.2	83	42	351	64	8.5	34	0.05	0.77	0.6	2.2
47	MZN-17B	Budhana Khadar	IM II	64	7.6	754	483	222	296	42	6.2	84	21	271	40	14.5	0.2	0.02	0.76	0.4	1.4
48	MZN-17C	Budhana Khadar	BW(PS)	104	8.2	660	422	216	195	53	5.3	42	22	264	16	14	3.1	0.01	0.74	0.2	0.9
		Minimum			6.8	442	283	144	170	4.5	2.2	32	19	176	4.0	1.0	0.0	0.01	0.07	0.1	0.4
		Maximum			8.2	2520	1613	463	634	160	126	167	62	565	204	98	282	0.14	0.92	1.8	5.9
		Mean			7.5	871	557	255	325	34	10	75	33	311	36	25	30	0.05	0.35	0.6	2.1

Table 4.9 Bacteriological Data of Ground Water Samples of District Muzaffarnagar (March 2013)						
S.No.	**Sample ID**	**Location**	**Source**	**Depth**	**Total Coliform**	**Fecal Coliform**
				m	per 100 ml	per 100 ml
1	MZN-1B	Sujru	IM II	12	<3	<3
2	MZN-1C	Sujru	TW	30	<3	<3
3	MZN-2A	Lachhera	HP	21	23	<3
4	MZN-2B	Lachhera	IM II	37	4	<3
5	MZN-2C	Lachhera	TW	38	<3	<3
6	MZN-3A	Purbaliyan	HP	11	43	<3
7	MZN-3B	Purbaliyan	IM II	46	23	<3
8	MZN-3C	Purbaliyan	TW	67	<3	<3
9	MZN-4A	Jeewna	HP	14	<3	<3
10	MZN-4B	Jeewna	IM II	46	<3	<3
11	MZN-4C	Jeewna	TW	24	<3	<3
12	MZN-5A	Kilasa (Kitas)	HP	17	<3	<3
13	MZN-5B	Kilasa (Kitas)	IM II	76	<3	<3
14	MZN-5C	Kilasa (Kitas)	TW	61	<3	<3
15	MZN-6A	Rohana Khurd	HP	14	23	4
16	MZN-6B	Rohana Khurd	IM II	37	23	<3
17	MZN-6C	Rohana Khurd	TW	38	<3	<3
18	MZN-7A	Didaheri	HP	18	43	<3
19	MZN-7B	Didaheri	IM II	34	23	<3
20	MZN-7C	Didaheri	TW	32	<3	<3
21	MZN-8A	Kasoli	HP	24	<3	<3
22	MZN-8B	Kasoli	IM II	55	<3	<3
23	MZN-8C	Kasoli	TW	38	<3	<3
24	MZN-9A	Nagla Rai	HP	6	93	9
25	MZN-9B	Nagla Rai	IM II	38	23	<3
26	MZN-9C	Nagla Rai	TW	38	<3	<3
27	MZN-10A	Ladwa	HP	9	43	<3
28	MZN-10B	Ladwa	IM II	49	<3	<3
29	MZN-10C	Ladwa	TW	27	<3	<3
30	MZN-11A	Atali	HP	14	23	4
31	MZN-11B	Atali	IM II	24	43	<3
32	MZN-12A	Hadoli	HP	15	<3	<3
33	MZN-12B	Hadoli	IM II	40	<3	<3
34	MZN-12C	Hadoli	TW	46	<3	<3
35	MZN-13A	Titawi	HP	17	<3	<3
36	MZN-13B	Titawi	IM II	46	<3	<3
37	MZN-14A	Inchauli	HP	21	<3	<3
38	MZN-14B	Inchauli	IM II	55	<3	<3
39	MZN-14C	Inchauli	TW	21	<3	<3
40	MZN-15A	Rampur	HP	18	<3	<3
41	MZN-15B	Rampur	IM II	46	<3	<3
42	MZN-15C	Rampur	TW	61	<3	<3
43	MZN-16A	Chandsina	HP	17	93	4
44	MZN-16B	Chandsina	IM II	46	23	<3
45	MZN-16C	Chandsina	TW	61	<3	<3
46	MZN-17A	Budhana Khadar	HP	31	23	<3
47	MZN-17B	Budhana Khadar	IM II	64	<3	<3
48	MZN-17C	Budhana Khadar	BW(PS)	104	<3	<3

Table 4.10 Trace Element Data of Ground Water Samples of District Muzaffarnagar (March 2013)													
S.No.	**Sample ID**	**Location**	**Source**	**Depth**	**Fe**	**Mn**	**Cu**	**Ni**	**Cr**	**Pb**	**Cd**	**Zn**	**As**
				m	**μg/L**	**μg/L**	**μg/L**	**μg/L**	**μg/L**	**μg/L**	**μg/L**	**μg/L**	**μg/L**
1	MZN-1B	Sujru	IM II	12	1066	7.0	14	70	13	56	6.0	122	ND
2	MZN-1C	Sujru	TW	30	57	61	13	ND	ND	ND	9.0	56	ND
3	MZN-2A	Lachhera	HP	21	44	ND	12	58	16	65	4.0	189	ND
4	MZN-2B	Lachhera	IM II	37	2002	90	13	37	ND	66	2.0	148	ND
5	MZN-2C	Lachhera	TW	38	29	37	13	30	6	63	1.0	19	ND
6	MZN-3A	Purbaliyan	HP	11	495	3.0	12	45	26	29	ND	105	ND
7	MZN-3B	Purbaliyan	IM II	46	1033	119	15	53	18	ND	4.0	132	ND
8	MZN-3C	Purbaliyan	TW	67	41	73	11	25	5.0	2.0	1.0	58	ND
9	MZN-4A	Jeewna	HP	14	1928	45	16	60	ND	77	9.0	142	ND
10	MZN-4B	Jeewna	IM II	46	144	32	13	15	ND	61	1.0	136	ND
11	MZN-4C	Jeewna	TW	24	351	66	13	12	ND	49	ND	134	ND
12	MZN-5A	Kilasa (Kitas)	HP	17	1302	121	15	ND	ND	54	ND	155	ND
13	MZN-5B	Kilasa (Kitas)	IM II	76	476	163	15	10	ND	123	3.0	78	ND
14	MZN-5C	Kilasa (Kitas)	TW	61	273	42	16	35	ND	77	1.0	62	ND
15	MZN-6A	Rohana Khurd	HP	14	373	16	15	31	ND	94	ND	162	ND
16	MZN-6B	Rohana Khurd	IM II	37	543	164	14	3.0	8.0	80	ND	148	ND
17	MZN-6C	Rohana Khurd	TW	38	79	21	13	27	ND	63	ND	82	ND
18	MZN-7A	Didaheri	HP	18	2467	28	26	7.0	ND	52	ND	169	ND
19	MZN-7B	Didaheri	IM II	34	993	122	14	9.0	ND	ND	15	96	ND
20	MZN-7C	Didaheri	TW	32	32	8.0	15	29	9.0	41	12	72	ND
21	MZN-8A	Kasoli	HP	24	ND	125	16	ND	ND	ND	13	155	ND
22	MZN-8B	Kasoli	IM II	55	1042	65	15	27	ND	40	8.0	62	ND
23	MZN-8C	Kasoli	TW	38	12	111	16	16	17	84	7.0	55	ND
24	MZN-9A	Nagla Rai	HP	6	867	15	29	53	10	115	8.0	168	ND
25	MZN-9B	Nagla Rai	IM II	38	1097	460	20	9.0	ND	64	2.0	65	ND
26	MZN-9C	Nagla Rai	TW	38	211	9.0	18	14	ND	55	10	58	ND
27	MZN-10A	Ladwa	HP	9	875	699	20	46	5.0	65	6.0	180	ND
28	MZN-10B	Ladwa	IM II	49	289	136	20	26	1.0	49	8.0	58	ND
29	MZN-10C	Ladwa	TW	27	209	44	19	41	5.0	63	4.0	62	ND
30	MZN-11A	Atali	HP	14	1268	171	16	25	4.0	59	9.0	76	ND
31	MZN-11B	Atali	IM II	24	1406	78	20	7	25	ND	57	146	ND
32	MZN-12A	Hadoli	HP	15	1119	319	19	20	13	33	3.0	164	ND
33	MZN-12B	Hadoli	IM II	40	3043	186	21	44	21	39	ND	84	ND
34	MZN-12C	Hadoli	TW	46	115	54	17	21	ND	67	ND	72	ND
35	MZN-13A	Titawi	HP	17	252	153	19	39	ND	55	4.0	66	ND
36	MZN-13B	Titawi	IM II	46	1491	117	28	ND	ND	30	8.0	47	ND
37	MZN-14A	Inchauli	HP	21	1063	22	290	ND	ND	38	1.0	82	ND
38	MZN-14B	Inchauli	IM II	55	362	5	11	ND	ND	ND	ND	64	ND
39	MZN-14C	Inchauli	TW	21	81	15	8.0	5.0	8.0	28	1.0	46	ND
40	MZN-15A	Rampur	HP	18	3227	149	11	72	13	32	4.0	102	ND
41	MZN-15B	Rampur	IM II	46	402	95	9.0	38	ND	ND	2.0	66	ND
42	MZN-15C	Rampur	TW	61	73	25	6.0	ND	ND	39	4.0	42	ND
43	MZN-16A	Chandsina	HP	17	4772	931	21	33	ND	31	11	16	ND
44	MZN-16B	Chandsina	IM II	46	508	72	8.0	15	12	16	ND	54	ND
45	MZN-16C	Chandsina	TW	61	224	78	7.0	17	ND	ND	2.0	92	ND
46	MZN-17A	Budhana Khadar	HP	31	2487	210	165	ND	10	61	7.0	45	ND
47	MZN-17B	Budhana Khadar	IM II	64	4225	110	16	39	28	7.0	11	58	ND
48	MZN-17C	Budhana Khadar	BW(PS)	104	111	113	10	24	6.0	1.0	8.0	32	ND
		Minimum			12	3.0	6.0	3.0	1.0	1.0	1.0	16	ND
		Maximum			4772	931	290	72	28	123	57	189	ND
		Mean			948	123	24	30	12	53	7.2	93	ND

4.2.3 District Shamli

Total 41 ground water samples from private hand pumps, IM II hand pumps and tube wells/bore wells were collected from 14 villages in the buffer zone of 2 km on the banks of River Krishni falling in District Shamli (Fig. 4.6) and the results (Tables 4.11 to 4.13) have been discussed in the following sections.

General Characteristics

The pH values in the ground water samples collected from District Shamli fall within the range of 6.7 to 7.7 in private hand pumps, 6.9 to 7.7 in IM II hand pumps and 7.0 to 8.2 in tube wells/bore wells. The pH values for all of the samples are well within the limits prescribed by BIS (2012) for various uses of water including drinking and other domestic supplies.

The electrical conductivity and dissolved salt concentrations are directly related to the concentration of ionized substance in water and may also be related to problems of excessive hardness and/or other mineral contamination. The conductivity values in the ground water samples vary from 467 to 1181 μS/cm in private hand pumps, 601 to 1462 μS/cm in IM II hand pumps and 576 to 1220 μS/cm in tube wells/bore wells. The conductivity above 1000 μS/cm was observed in about 79%, 57% and 31% samples of private hand pumps, IM II hand pumps and tube wells/bore wells respectively. The maximum conductivity value of 1846 μS/cm was observed in the hand pump of village Bantikhera.

The TDS value in the ground water samples collected from District Shamli varies from 467 to 1181 mg/L in private hand pumps, 385 to 936 mg/L in IM II hand pumps and 369 to 781 mg/L in tube wells/bore wells. TDS values above the acceptable limit of 500 mg/L were observed in 93%, 64% and 62% samples of private hand pumps, IM II hand pumps and tube wells/bore wells respectively. Water containing more than 500 mg/L of TDS is not considered acceptable for drinking water supplies, though more highly mineralized water is also used where better water is not available. For this reason, 500 mg/L as the acceptable limit and 2000 mg/L as the maximum permissible limit has been suggested for drinking water (BIS, 2012). None of the collected samples from District Shamli exceeded the permissible limit of 2000 mg/L. Water containing TDS more than 500 mg/L causes gastrointestinal irritation.

Alkalinity in natural water is mainly due to presence of carbonates, bicarbonates and hydroxides. Bicarbonates represent the major form since they are formed in considerable amount from the action of carbonates upon the basic materials in the soil. The alkalinity value in the collected samples from District Shamli varies from 260 to 516 mg/L in private hand pumps, 222 to 478 mg/L in IM II hand pumps and 216 to 428 mg/L in tube wells/bore wells. All of the samples collected from private hand pumps, IM II hand pumps and tube wells/bore wells exceeded the acceptable limit of 200 mg/L but within the maximum permissible limit of 600 mg/L.

Hardness of water is due to carbonates, sulphates and chlorides of calcium and magnesium. A limit of 200 mg/L as acceptable limit and 600 mg/L as permissible limit has been recommended for drinking water (BIS, 2012). The total hardness values in the samples collected

from District Shamli range from 174 to 606 mg/L in private hand pumps, 144 to 384 mg/L in IM II hand pumps and 179 to 325 mg/L in tube wells/bore wells. The ground water sample collected from private hand pumps of village Chandenamal crossed the permissible limit of 600 mg/L.

In ground water of the samples collected from District Shamli, the values of calcium range from 32 to 157 mg/L in private hand pumps, 28 to 116 mg/L in IM II hand pumps and 29 to 59 mg/L in tube wells/bore wells and the values of magnesium range from 10 to 52 mg/L in private hand pumps, 15 to 46 mg/L in IM II hand pumps and 25 to 53 mg/L in tube wells/bore wells. The acceptable limit for calcium and magnesium for drinking water are 75 and 30 mg/L respectively (BIS, 2012). In ground water, the calcium content generally exceeds the magnesium content in accordance with their relative abundance in rocks. All ground water samples collected from District Shamli fall within the maximum permissible limit of 200 mg/L of calcium and 100 mg/L of magnesium**.**

The concentration of sodium in the the samples collected from District Shamli varies from 40 to 180 mg/L in private hand pumps, 22 to 155 mg/L in IM II hand pumps and 23 to 140 mg/L in tube wells/bore wells. The Bureau of Indian Standards has not included sodium in drinking water standards. The high sodium values in the collected samples may be attributed to base-exchange phenomena and causes sodium hazard. Ground water with such high sodium is not suitable for irrigation purpose.

Potassium is an essential element for humans, plants and animals and derived in food chain mainly from vegetation and soil. The main sources of potassium in ground water include rain water, weathering of potash silicate minerals, use of potash fertilizers and use of surface water for irrigation. The concentration of potassium in the ground water samples collected from District Shamli varies from 5.5 to 10 mg/L in private hand pumps, 4.1 to 8.0 mg/L in IM II hand pumps and 4.4 to 8.0 mg/L in tube wells/bore wells. The Bureau of Indian Standards has not included potassium in drinking water standards. However, the European Economic Community has prescribed guideline level of potassium at 10 mg/L in drinking water. As per EEC criteria, all the ground water samples collected from District Shamli falls within the guideline level of 10 mg/L.

The concentration of chloride in the samples collected from District Shamli varies from 6.0 to 118 mg/L in private hand pumps, 2.0 to 138 mg/L in IM II hand pumps and 2.0 to 20 mg/L in tube wells/bore wells. All samples were observed within the acceptable limit of 250 mg/L. The limits of chloride have been laid down primarily from taste considerations. A limit of 250 mg/L chloride has been recommended as acceptable limit and 1000 mg/L as the permissible limit for drinking water (BIS, 2012). However, no adverse health effects on humans have been reported from intake of waters containing even higher content of chloride. The concentration of sulphate in the samples collected from District Shamli varies from 1.0 to 95 mg/L in private hand pumps, 2.5 to 63 mg/L in IM II hand pumps and 1.5 to 51 mg/L in tube wells/bore wells. Bureau of Indian standard has prescribed 200 mg/L as the acceptable limit and 400 mg/L as the permissible limit for sulphate in drinking water. In the samples collected from District Shamli, none of the samples exceeded the maximum acceptable limit of 200 mg/L.

Nitrate content in drinking water is considered important for its adverse health effects and moderately toxicity. A limit of 45 mg/L has been prescribed by BIS (2012) for drinking water supplies. Its concentration above 45 mg/L may prove detriment to human health. In higher concentrations, nitrate may produce a disease known as methaemoglobinaemia (blue babies) which generally affects bottle-fed infants. Repeated heavy doses of nitrates on ingestion may also cause carcinogenic diseases. The nitrate content in the samples collected from District Shamli varies from 0 to 109 mg/L in private hand pumps, 0 to 16 mg/L in IM II hand pumps and 0 to 15 mg/L in tube wells/bore wells. The nitrate concentration was observed more than permissible limit of 45 mg/L in ground water samples from private hand pump of village Harad Fatehpur, which may be attributed to contamination by industrial/domestic waste disposal.

The presence of fluoride in ground water may be attributed to the localized effects of natural sources. The fluoride is present in soil strata due to the presence of geological formations like fluorspar, fluorapatite, ampheboles such as hornblinde, trimolite and mica. Weathering of alkali, silicate, igneous and sedimentary rocks specially shales contribute a major portion of fluorides to ground waters. In addition to natural sources, considerable amount of fluorides may be contributed due to man's activities. Fluoride salts are commonly used in steel, aluminium, bricks and tile-industries. The fluoride containing insecticides and herbicides may be contributed through agricultural runoff. Phosphatic fertilizers, which are extensively used, often contain fluorides as impurity and these may increase levels of fluoride in soil. The accumulation of fluoride in soil eventually results in its leaching due to percolating water, thus increase fluoride concentration in ground water. The fluoride content in the ground water samples collected from District Shamli varies from 0.30 to 0.79 mg/L in private hand pumps, 0.24 to 1.69 mg/L in IM II hand pumps and 0.24 to 0.86 mg/L in tube wells/bore wells. Ground water samples collected from all villages of the District Shamli fall within the acceptable limit of 1.0 mg/L except village Lisarh and Jalalabad. The ground water sample collected from IM II hand pump even exceeded the maximum permissible limit of 1.5 mg/L.

From the above discussion, it is clearly evident that in the ground water samples collected from District Shamli, the concentration of total dissolved solids was found to exceed acceptable limit of 500 mg/L in more than 93%, 64% and 62% samples of private hand pumps, IM II hand pumps and tube wells/bore wells respectively but none of the samples exceeded the permissible limit of 2000 mg/L. The hardness values exceed the permissible limit in ground water sample collected from the private hand pump of village Chandenamal. The concentration of nitrate exceeded the permissible limit in ground water samples collected from the hand pump of Harad Fatehpur. The concentration of fluoride was observed within the acceptable limit in all the collected samples except village Lisarh and Jalalabad. The violation of BIS limit could not be ascertained for sodium and potassium as no permissible limit for these constituents has been prescribed in BIS drinking water specifications. On the basis of above results, it can be inferred that ground water from private hand pumps have the problem of TDS, hardness and nitrate specially in the area of Chandenamal and Harad Fatehpur, which may be attributed to possible impact of effluents discharged into river Krishni on the ground water.

Bacteriological Parameters

In water quality control technology, the principal indicator of suitability of water for domestic, industrial or other uses is the coliform group of bacteria. The density of coliform group is the criteria for the extent of contamination and has been the basis for bacteriological water quality standard. Further, the presence of faecal colifirms in water is the indicator of a potential public health problem, because faecal matter is a source of pathogenic bacteria and viruses. The faecal coliform bacteria contaminate water through percolation from contamination sources (domestic sewage and septic tank) and also because of poor sanitary system. The indiscriminate land disposal of domestic waste on surface and improper disposal of solid waste further aggravate the problem of bacterial contamination in water. The collected samples from District Shamli were analysed for bacteriological parameters viz; Total Coliform and Faecal Coliform. The result of bacteriological analysis is given in Table 4.12. The result shows that the bacterial contamination was observed in seven ground water samples of five villages of District Shamli.

Heavy Metals

Heavy metals in ground water have a considerable significance due to their toxicity and adsorption behaviour. Heavy metals are not biodegradable and enter the food chain through a number of pathways causing progressive toxicity due to the accumulation in human and animal organs during their life span on long term exposure to contaminated environments. Despite the presence of trace concentrations of Cr, Mn, Co, Cu and Zn in the aquatic environment, which is essential to a number of life processes, high concentrations of these metals become toxic. The major sources of heavy metals in ground water include weathering of rock minerals, discharge of sewage and other waste effluents on land and runoff water. The trace element data of ground water samples collected from the District Shamli is given in Table 4.13. The distribution of different metals is shown graphically in Fig. 4.7. The toxic effects of these elements and extent of their contamination in ground water is discussed in the following sections.

Iron (Fe): The concentration of iron in the ground water samples collected from District Shamli ranges from 0.272 to 9.830 mg/L in private hand pumps, 0.085 to 7.450 mg/L in IM II hand pumps and 0.025 to 3.208 mg/L in tube wells/bore wells. The Bureau of Indian Standards has recommended 0.3 mg/L as the acceptable limit for iron in drinking water (BIS, 2012). WHO has prescribed 0.3 mg/L as the acceptability threshold value for iron (WHO, 2011). It is evident from the results that about 93% samples of private hand pumps, 71% samples of IM II hand pumps and 31% of tube wells/bore wells exceed the acceptable limit of 0.3 mg/L. High concentration of iron was observed in the ground water of Lisarh, Sunna, Bhanera, Kudana, Bantikhera, Chandenamal, Dabheri, Jalalabad, Raipur and Masavi . The higher concentration of iron in the ground water may be attributed to leaching of industrial wastes flowing into the river Krishni.

It is a known fact that iron in trace amounts is essential for nutrition. High concentrations of iron generally cause inky flavour, bitter and astringent taste to water. Well water containing soluble iron remain clear while pumped out, but exposure to air causes precipitation of iron due to oxidation, with a consequence of rusty colour and turbidity. The objection to iron in the distribution system is not due to health reason but to staining of laundry and plumbing fixtures and appearance. Taste and order problems may be caused by filamentous organism that prey on iron compounds (frenothrix, gallionella and leptothrix are called iron bacteria), originating another consumer's objection (red water). The presence of iron bacteria may clog well screens or develop in the distribution system, particularly when sulphate compounds in addition to iron may be subjected to chemical reduction.

Manganese (Mn): The concentration of manganese in the ground water samples collected from District Shamli ranges from 0.027 to 1.754 mg/L in private hand pumps, 0.031 to 0.382 mg/L in IM II hand pumps and 0.046 to 0.307 mg/L in tube wells/bore wells. Manganese is an essential trace nutrient for plants and animals, which does not occur naturally as a metal but is found in various salts and minerals frequently in association with iron compounds. Manganese may gain entry into the body by inhalation, consumption of food and through drinking water. A concentration of 0.1 mg/L has been recommended as an acceptable limit and 0.3 mg/L as the permissible limit for drinking water (BIS, 2012). WHO has prescribed 0.1 mg/L as the acceptability threshold value and 0.4 mg/L as health based value (WHO, 2011). It is evident from the results that about 21% of the samples collected from the private hand pumps, 29% from IM II hand pumps and 39% samples from tube wells/bore wells fall within the acceptable limit of 0.1 mg/L and three samples from private hand pumps and one sample each from IM II hand pump and bore well exceed the maximum permissible limit of 0.3 mg/L. The presence of manganese above permissible limit of drinking water often imparts alien taste to water. It also has adverse effects on domestic uses and water supply structures.

Copper (Cu): The concentration of copper in the ground water samples collected from District Shamli ranges from 0.005 to 0.444 mg/L in private hand pumps, 0.003 to 0.057 mg/L in IM II hand pumps and 0.001 to 0.017 mg/L in tube wells/bore wells. The Bureau of Indian Standards has recommended 0.05 mg/L as the acceptable limit and 1.5 mg/L as the permissible limit in the absence of alternate source (BIS, 2012). Beyond 0.05 mg/L the water imparts astringent taste and cause discoloration and corrosion of pipes, fittings and utensils. World Health Organization has recommended 2.0 mg/L as the provisional guideline value for drinking purpose (WHO, 2011). In the present investigation, one sample collected from private hand pumps of village Harad Fatehpur and one sample collected from IM II hand pump of village Kudana of the District Shamli exceed the acceptable limit of 0.05 mg/L.

Nickel (Ni): The concentration of nickel in the ground water samples collected from District Shamli ranges from ND to 0.067 mg/L in private hand pumps, ND to 0.073 mg/L in IM II hand pumps and ND to 0.060 mg/L in tube wells/bore wells. The Bureau of Indian Standards has recommended 0.02 mg/L as the acceptable limit (BIS, 2012). World Health Organization has recommended 0.07 mg/L as the guideline value for drinking purposes (WHO, 2011). In this range it is not harmful in drinking water. About 64%, 50% and 53% of samples each from private hand pumps, IM II hand pumps and bore wells/tube wells exceed the BIS limit of 0.02 mg/L.

Chromium (Cr): The concentration of chromium in the ground water samples collected from District Shamli ranges from 0.002 to 0.046 mg/L in both private hand pumps, and IM II hand pumps and ND to 0.042 mg/L in tube wells/bore wells. A concentration of 0.05 mg/L has been recommended as an acceptable limit for drinking water (BIS, 2012). WHO has also prescribed 0.05 mg/L as the guideline value for drinking water (WHO, 2011). None of the samples exceeds the BIS limit of 0.05 mg/L.

Hexavalent chromium has a deleterious effect on the liver, kidney, and respiratory organs with hemorrhagic effects, dermatitis, and ulceration of the skin for chronic and subchronic exposure. Municipal wastewater release considerable amount of chromium into the environment. In the natural environment, Cr(+6) is likely to be reduced to Cr(+3), thereby reducing the toxic impact of chromium discharges. The pathways of chromium contribution to ground water are that the chromium containing industrial effluent discharged into stream, the hexavalent state chromium may be reduced to trivalent state and later adsorbed on the suspended particulate. In case, it could not be adsorbed, the chromium remain in the form of colloidal suspension, may precipitate and become part of stream sediment, from where it may reach to ground water through percolation containing shallow aquifers.

Lead (Pb): In the ground water samples collected from District Shamli, the concentration of lead ranges from 0.005 to 0.192 mg/L in private hand pumps, ND to 0.112 mg/L in IM II hand pumps and ND to 0.081 mg/L in tube wells/bore wells. The Bureau of Indian Standards has prescribed 0.01 mg/L lead as the desirable limit for drinking water (BIS, 2012). Beyond this limit, the water becomes toxic. WHO has also prescribed 0.01 mg/L as guideline value for drinking water (WHO, 2011). About 93%, 86% and 92% of samples each from private hand pumps, IM II hand pumps and bore wells/tube wells exceed the BIS limit of 0.01 mg/L.

Lead is not considered an essential nutritional element and is a cumulative poison to humans. Acute lead poisoning is extremely rare. The typical symptoms of advanced lead poisoning are constipation, anemia, gastrointestinal disturbance, tenderness and gradual paralysis in muscles, specifically arms with possible cases of lethargy and moroseness. The major source of lead contamination is the combustion of fossil fuel. Lead is removed from the atmosphere by rain and falls back on the earth surface and seeps into the ground. Lead passes from the soil to water and to the plants and finally into the food chain. In drinking water it occurs primarily due to corrosion of lead pipes and solders, especially in areas of soft water. It may be noted that the use of soft water of slightly acidic pH and the use of lead pipes in service and domestic water lines may provide higher concentrations of lead at the consumers's tap, particularly when the water use is minimal in the household (overnight still water in pipes).

Cadmium (Cd): In the ground water samples collected from District Shamli, the concentration of cadmium ranges from ND to 0.046 mg/L in private hand pumps, ND to 0.047 mg/L in IM II hand pumps and ND to 0.041 mg/L in tube wells/bore wells. The Bureau of Indian Standards has prescribed 0.003 mg/L cadmium as the acceptable limit for drinking water (BIS, 2012). Beyond this limit, the water becomes toxic. WHO has also prescribed 0.003 mg/L cadmium as the guideline value for drinking water (WHO, 2011). The drinking water having more than 3 µg/L of cadmium can cause bronchitis, emphysema, anaemia and renal stone formation in animals. About 64% samples from private hand pumps, 36% samples from IM II hand pumps and 54% samples from tube wells/bore wells exceed the BIS limit of 0.003 mg/L.

Zinc (Zn): The concentration of zinc in the ground water samples collected from District Shamli ranges from 0.025 to 0.135 mg/L in private hand pumps, 0.065 to 0.270 mg/L in IM II hand pumps and 0.021 to 0.136 mg/L in tube wells/bore wells. The Bureau of Indian Standards has prescribed 5.0 mg/L zinc as the acceptable limit and 15 mg/L as the permissible limit for drinking water (BIS, 2012). WHO has prescribed 3.0 mg/L as the guideline value for drinking water (WHO, 2011). All the samples were found within the desirable limit prescribed by BIS (2012) and WHO (2011).

Arsenic (As): In the ground water samples collected from District Shamli, the concentration of arsenic was not detected. Ground water is expected to contain higher arsenic concentrations than surface water. Because of its presence in geological materials, arsenic can be traced in water as originated by natural processes or by industrial activities – industrial waste, arsenical pesticides and smelting operations. Generally, arsenic found in two state – As(III) and As(V) in ground water. As(III) compounds are more toxic than As(V) compounds. Arsenic compounds are skin and lung carcinogens in humans. The Bureau of Indian Standards has prescribed 0.01 mg/L arsenic as the acceptable limit and 0.05 mg/L as the permissible limit for drinking water (BIS, 2012). Beyond this limit, the water becomes toxic. WHO has prescribed 0.01 mg/L arsenic as the guideline value for drinking water (WHO, 2011). In the present investigation, all the ground water samples collected from District Shamli were found within the acceptable limit prescribed by BIS (2012).

From the above results, it is quite clear that the presence of heavy metals has been recorded in many location and the water quality standards have been violated for iron (13 samples from private hand pumps, 10 samples from IM II hand pumps and 4 sample from bore wells/tube wells), manganese (3 samples from private hand pumps and 1 sample each from IM II hand pump and bore well), copper (1 sample each from private hand pump and IM II hand pump), nickel (9 samples from private hand pumps, 7 samples each from IM II hand pumps and tube wells/bore wells), lead (13 samples from private hand pumps, 12 samples each from IM II hand pumps and tube wells/bore wells), Cadmium (9 samples from private hand pumps, 5 samples from IM II hand pumps and 7 samples from tube wells/bore wells) out of collected 14 samples each from private hand pumps and IM II hand pumps and 13 samples from tube wells/bore wells of District Shamli.

Pesticides

The analysis of nine organo-chlorinated pesticides (Aldrin, α-BHC, β-BHC, γ-BHC, δ-BHC, DDD, DDE, Endosulphan and Methoxychlor) was carried out in ground water samples from IM II hand pump of Chandenamal and Masavi of District Shamli. Out of the nine chlorinated pesticides analysed, only one pesticide γ-BHC has been detected in ground water of village Masavi (20.148 µg/L). The concentration of γ-BHC pesticide exceeds the permissible limit in the ground water sample of Masawi. The presence of γ-BHC in ground water may be attributed due to their use in agricultural activities and for vector control programmes. The pesticide applied on surface might have leached through soil strata under the influence of hydraulic gradient and become source of contamination in ground water.

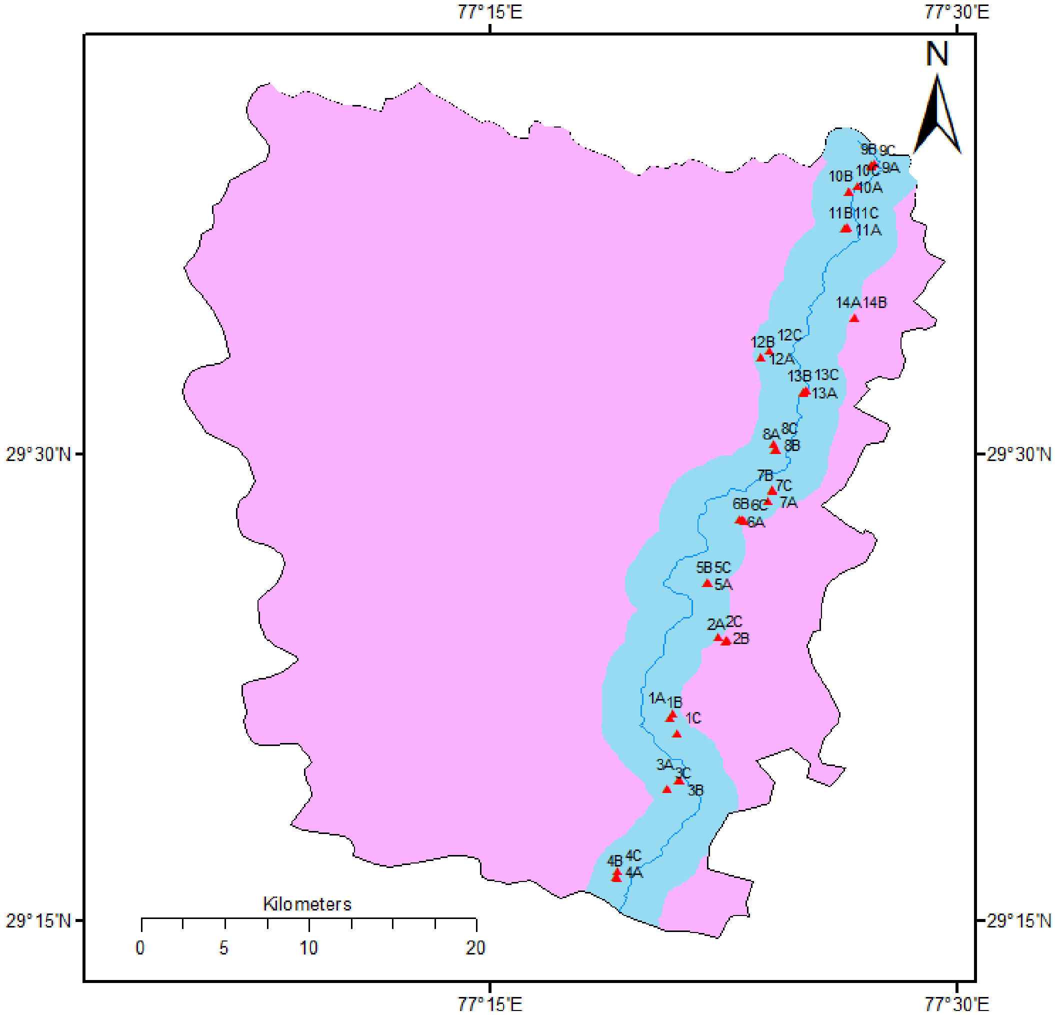


Fig. 4.6 Ground Water Sampling Locations in District Shamli in Two km Buffer Zone of River Krishni

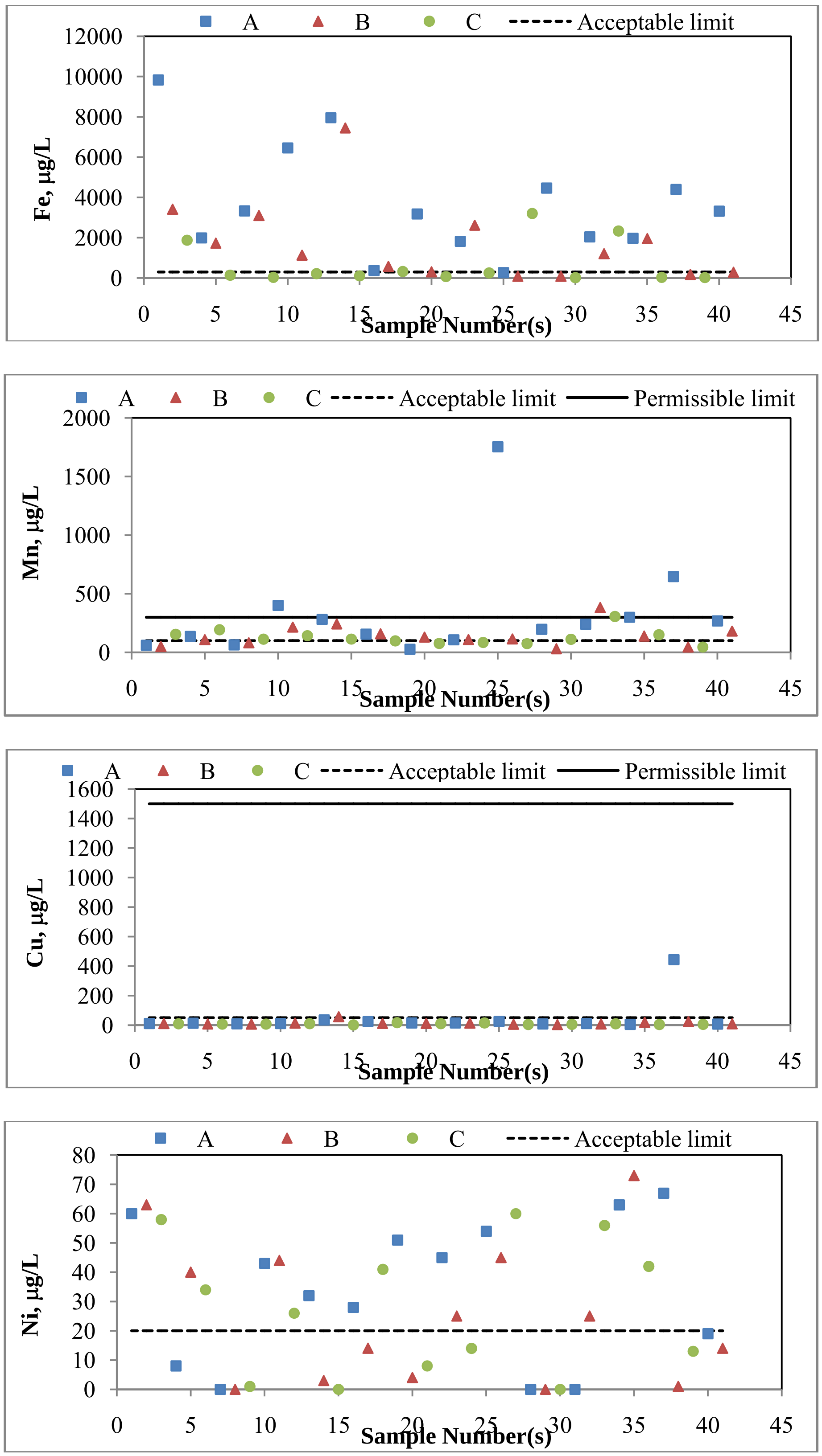


Fig. 4.7 Distribution of Trace Elements in Ground Water of District Shamli

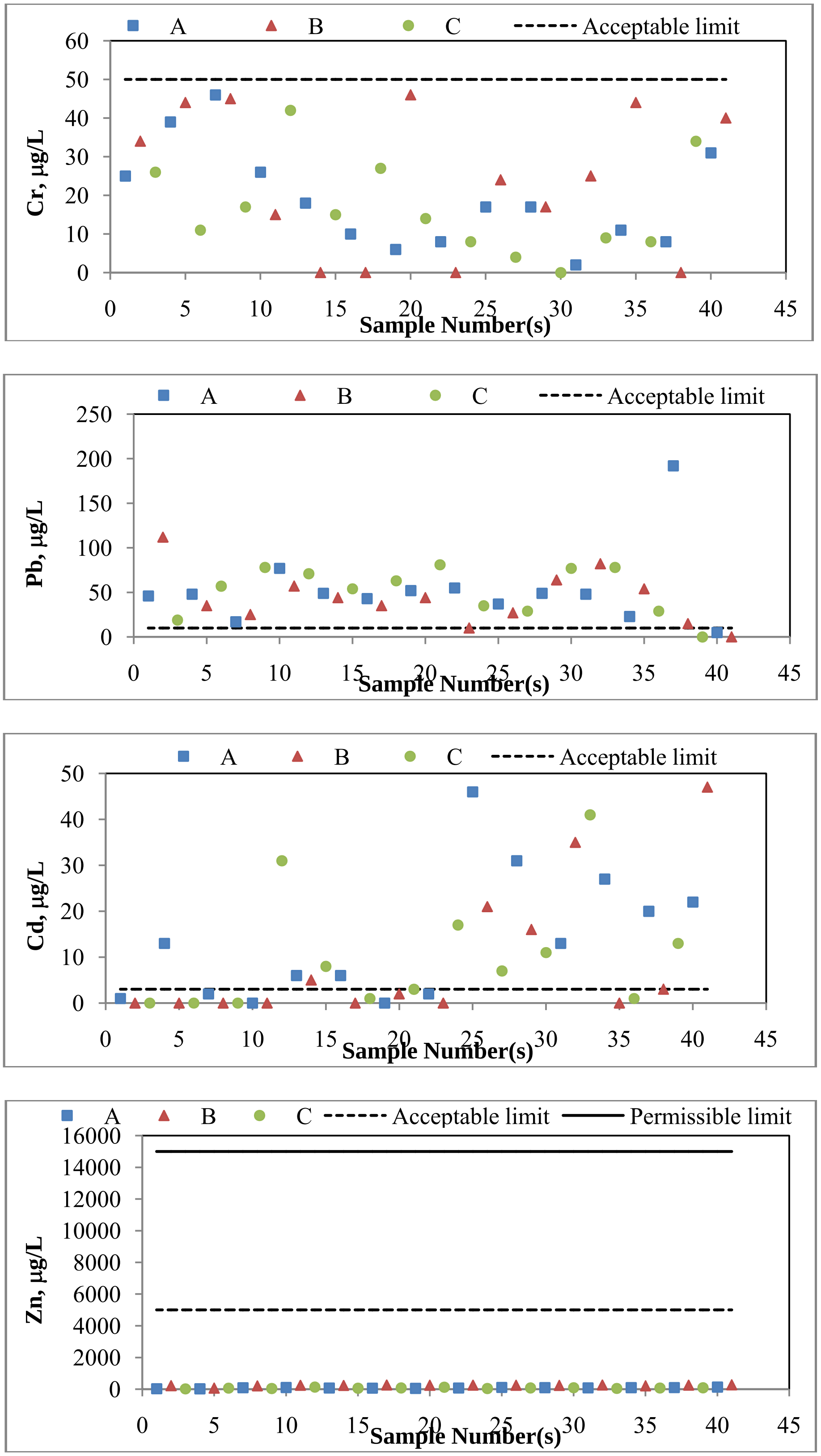


Fig. 4.7 (Contd.) Distribution of Trace Elements in Ground Water of District Shamli

Table 4.11 Hydro-chemical Data of Ground Water Samples of District Shamli (March 2013)

S.No.	Sample ID	Location	Source	Depth	pH	EC	TDS	Alk	Hard	Na	K	Ca	Mg	HCO3	Cl	SO4	NO3	PO4	F	BOD	COD
				m		μS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1	SML-1A	Lisarh	HP	41	7.7	730	467	260	174	62	6.5	32	23	317	14	1.0	8.6	0.12	0.79	1.0	2.8
2	SML-1B	Lisarh	IM II	73	7.4	626	401	224	144	56	4.1	33	15	273	2.0	13	0.9	0.02	1.39	0.4	1.0
3	SML-1C	Lisarh	TW	73	7.0	1220	781	428	216	140	8.3	42	27	522	18	17	2.9	0.03	0.86	0.2	0.4
4	SML-2A	Bahawari	HP	70	7.2	800	512	296	259	41	5.5	41	38	361	18	4.0	0	0.02	0.77	0.8	2.1
5	SML-2B	Bahawari	IM II	73	7.2	714	457	276	217	40	4.8	41	28	337	2.0	3.5	0	0.02	0.68	0.4	1.0
6	SML-2C	Bahawari	TW	82	7.2	896	573	338	256	56	5.6	40	38	412	8.0	4.5	4.3	0.02	0.85	0.2	0.8
7	SML-3A	Sunna	HP	58	7.4	806	516	288	227	51	5.7	43	29	351	16	16	1.7	0.05	0.54	0.5	1.6
8	SML-3B	Sunna	IM II	55	7.3	825	528	302	223	49	5.6	50	24	368	10	15	1.1	0.04	0.74	0.4	1.0
9	SML-3C	Sunna	TW	70	7.2	998	639	374	291	63	5.9	59	35	456	4.0	4.5	8.5	0.08	0.35	0.3	0.7
10	SML-4A	Bhanera	HP	30	7.1	1248	799	384	355	88	5.7	96	28	468	68	40	1.2	0.04	0.48	0.8	2.8
11	SML-4B	Bhanera	IM II	61	6.9	1462	936	478	296	155	6.9	69	30	583	18	53	16	0.18	0.65	0.6	2.4
12	SML-4C	Bhanera	TW	58	7.6	952	609	358	248	61	5.5	45	33	437	2.0	22	0.9	0.02	0.58	0.6	2.2
13	SML-5A	Kudana	HP	30	7.3	1362	872	502	238	132	7.8	79	10	612	6.0	9.5	9.3	0.06	0.71	1.2	3.2
14	SML-5B	Kudana	IM II	73	7.5	1246	797	462	261	114	7.5	52	32	564	10	11	0.5	0.02	0.47	0.6	1.6
15	SML-5C	Kudana	TW	53	7.6	1110	710	422	325	62	6.8	43	53	515	14	3.0	9.7	0.08	0.5	0.6	1.6
16	SML-6A	Kheri Bairagi	HP	62	7.6	1156	740	402	321	78	7.1	51	47	490	38	18	5.1	0.08	0.35	1.1	3.8
17	SML-6B	Kheri Bairagi	IM II	49	7.5	1080	691	408	214	100	5.9	28	35	498	10	5.5	6.0	0.06	0.45	0.8	2.6
18	SML-6C	Kheri Bairagi	TW	70	7.9	1110	710	422	225	100	6.3	34	34	515	8.0	1.5	9.5	0.06	0.41	0.4	2.2
19	SML-7A	Bantikhera	HP	21	7.3	1846	1181	516	440	180	9.1	107	42	630	118	56	35	0.12	0.69	0.8	2.1
20	SML-7B	Bantikhera	IM II	49	7.6	1108	709	402	264	99	4.6	30	46	490	18	11	4.2	0.04	0.51	0.4	2.4
21	SML-7C	Bantikhera	TW	76	7.8	1026	657	352	245	87	5.6	52	28	429	20	18	15	0.04	0.45	0.2	1.8
22	SML-8A	Kairi	HP	30	7.2	1310	838	455	351	95	10	101	24	555	18	25	7.3	0.06	0.37	0.9	2.4
23	SML-8B	Kairi	IM II	61	7.2	1102	705	352	357	51	6.9	97	28	429	50	35	2.5	0.04	0.66	0.4	1.0
24	SML-8C	Kairi	BW(PS)	183	8.2	702	449	266	203	44	4.8	32	30	325	6.0	2.0	0	0.02	0.24	0.2	0.4
25	SML-9A	Chandenamal	HP	14	6.7	1512	968	476	606	40	9.2	157	52	581	68	58	0	0.02	0.30	1.80	4.8
26	SML-9B	Chandenamal	IM II	30	7.6	640	410	226	207	32	4.8	32	31	276	8.0	20	2.7	0.04	0.38	1.2	2.8
27	SML-9C	Chandenamal	BW(PS)	122	7.7	588	376	226	179	29	5.2	29	26	276	6.0	1.5	2.5	0.04	0.38	0.2	0.8
28	SML-10A	Dabheri	HP	9	7.0	1385	886	401	395	89	6.8	114	27	489	90	65	0	0.02	0.39	1.4	3.6
29	SML-10B	Dabheri	IM II	30	7.6	602	385	228	216	22	4.9	34	32	278	8.0	2.5	0.2	0.01	0.69	0.4	2.6
30	SML-10C	Dabheri	TW	61	7.5	675	432	242	243	23	4.9	56	25	295	10	15	0.5	0.01	0.39	0.2	1.6
31	SML-11A	Jalalabad	HP	21	7.1	1365	874	406	355	102	6.8	96	28	495	88	45	5.8	0.04	ND	0.8	2.2
32	SML-11B	Jalalabad	IM II	34	7.1	1320	845	322	384	93	7.5	116	23	393	138	63	8.9	0.07	1.69	0.6	1.4
33	SML-11C	Jalalabad	BW(PS)	98	7.7	695	445	238	193	51	5.5	31	28	290	16	11	6.7	0.06	0.24	0.1	0.8
34	SML-12A	Harad Fatehpur	HP	27	7.3	1002	641	372	345	41	6.2	79	36	454	10	11	1.0	0.02	0.51	0.6	1.2
35	SML-12B	Harad Fatehpur	IM II	61	7.4	1099	703	385	231	105	6.3	68	15	470	22	11	4.6	0.04	0.24	0.2	0.8
36	SML-12C	Harad Fatehpur	TW	76	7.2	798	511	264	252	34	5.9	55	28	322	10	51	1.2	0.02	0.59	0.2	0.4
37	SML-13A	Raipur	HP	24	6.9	1696	1085	418	506	113	10.0	150	32	510	62	95	109	0.18	0.73	0.8	2.2
38	SML-13B	Raipur	IM II	55	7.7	601	385	222	193	32	4.3	31	28	271	12	5.0	0	0.02	0.84	0.4	1.4
39	SML-13C	Raipur	TW	61	7.6	576	369	216	180	31	4.4	31	25	264	4.0	6.0	0.7	0.01	0.45	0.4	1.6
40	SML-14A	Masavi	HP	24	7.1	1410	902	512	333	115	7.4	99	21	625	6.0	22	1.9	0.02	0.75	0.4	1.5
41	SML-14B	Masavi	IM II	40	7.2	1162	744	388	247	112	7.2	43	34	473	20	45	6.4	0.04	0.34	0.2	0.7
		Minimum			6.7	576	369	216	144	22	4.1	28	10	264	2.0	1.0	0.0	0.01	0.24	0.1	0.4
		Maximum			8.2	1846	1181	516	606	180	10	157	53	630	138	95	109	0.18	1.69	1.8	4.8
		Mean			7.4	1038	664	354	278	75	6.3	61	30	432	26	22	7.4	0.05	0.59	0.6	1.8

Table 4.12 Bacteriological Data of Ground Water Samples of District Shamli (March 2013)

S.No.	Sample ID	Location	Source	Depth	Total Coliform	Fecal Coliform
				m	per 100 ml	per 100 ml
1	SML-1A	Lisarh	HP	41	<3	<3
2	SML-1B	Lisarh	IM II	73	<3	<3
3	SML-1C	Lisarh	TW	73	<3	<3
4	SML-2A	Bahawari	HP	70	<3	<3
5	SML-2B	Bahawari	IM II	73	<3	<3
6	SML-2C	Bahawari	TW	82	<3	<3
7	SML-3A	Sunna	HP	58	<3	<3
8	SML-3B	Sunna	IM II	55	23	<3
9	SML-3C	Sunna	TW	70	<3	<3
10	SML-4A	Bhanera	HP	30	<3	<3
11	SML-4B	Bhanera	IM II	61	<3	<3
12	SML-4C	Bhanera	TW	58	<3	<3
13	SML-5A	Kudana	HP	30	<3	<3
14	SML-5B	Kudana	IM II	73	<3	<3
15	SML-5C	Kudana	TW	53	<3	<3
16	SML-6A	Kheri Bairagi	HP	62	<3	<3
17	SML-6B	Kheri Bairagi	IM II	49	<3	<3
18	SML-6C	Kheri Bairagi	TW	70	<3	<3
19	SML-7A	Bantikhera	HP	21	<3	<3
20	SML-7B	Bantikhera	IM II	49	23	<3
21	SML-7C	Bantikhera	TW	76	<3	<3
22	SML-8A	Kairi	HP	30	<3	<3
23	SML-8B	Kairi	IM II	61	<3	<3
24	SML-8C	Kairi	BW(PS)	183	<3	<3
25	SML-9A	Chandenamal	HP	14	150	4
26	SML-9B	Chandenamal	IM II	30	43	<3
27	SML-9C	Chandenamal	BW(PS)	122	<3	<3
28	SML-10A	Dabheri	HP	9	<3	<3
29	SML-10B	Dabheri	IM II	30	<3	<3
30	SML-10C	Dabheri	TW	61	<3	<3
31	SML-11A	Jalalabad	HP	21	43	<3
32	SML-11B	Jalalabad	IM II	34	23	<3
33	SML-11C	Jalalabad	BW(PS)	98	<3	<3
34	SML-12A	Harad Fatehpur	HP	27	<3	<3
35	SML-12B	Harad Fatehpur	IM II	61	<3	<3
36	SML-12C	Harad Fatehpur	TW	76	<3	<3
37	SML-13A	Raipur	HP	24	<3	<3
38	SML-13B	Raipur	IM II	55	<3	<3
39	SML-13C	Raipur	TW	61	<3	<3
40	SML-14A	Masavi	HP	24	240	9
41	SML-14B	Masavi	IM II	40	<3	<3

Table 4.13 Trace Element Data of Ground Water Samples of District Shamli (March 2013)

S.No.	Sample ID	Location	Source	Depth	Fe	Mn	Cu	Ni	Cr	Pb	Cd	Zn	As
				m	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
1	SML-1A	Lisarh	HP	41	9830	61	11	60	25	46	1	31	ND
2	SML-1B	Lisarh	IM II	73	3413	50	10	63	34	112	ND	218	ND
3	SML-1C	Lisarh	TW	73	1881	155	9	58	26	19	ND	21	ND
4	SML-2A	Bahawari	HP	70	1994	137	13	8	39	48	13	25	ND
5	SML-2B	Bahawari	IM II	73	1728	109	7	40	44	35	ND	65	ND
6	SML-2C	Bahawari	TW	82	143	194	7	34	11	57	ND	68	ND
7	SML-3A	Sunna	HP	58	3335	65	9	ND	46	17	2.0	95	ND
8	SML-3B	Sunna	IM II	55	3101	82	6	ND	45	25	ND	212	ND
9	SML-3C	Sunna	TW	70	39	113	7	1	17	78	ND	42	ND
10	SML-4A	Bhanera	HP	30	6458	401	11	43	26	77	ND	110	ND
11	SML-4B	Bhanera	IM II	61	1137	216	13	44	15	57	ND	248	ND
12	SML-4C	Bhanera	TW	58	220	143	10	26	42	71	31	136	ND
13	SML-5A	Kudana	HP	30	7959	282	35	32	18	49	6	78	ND
14	SML-5B	Kudana	IM II	73	7450	243	57	3	ND	44	5	238	ND
15	SML-5C	Kudana	TW	53	111	114	1	ND	15	54	8	62	ND
16	SML-6A	Kheri Bairagi	HP	62	375	156	24	28	10	43	6	66	ND
17	SML-6B	Kheri Bairagi	IM II	49	577	158	11	14	ND	35	ND	266	ND
18	SML-6C	Kheri Bairagi	TW	70	326	99	17	41	27	63	1	82	ND
19	SML-7A	Bantikhera	HP	21	3182	27	15	51	6	52	ND	56	ND
20	SML-7B	Bantikhera	IM II	49	304	131	11	4	46	44	2	244	ND
21	SML-7C	Bantikhera	TW	76	76	77	10	8	14	81	3	128	ND
22	SML-8A	Kairi	HP	30	1823	108	15	45	8	55	2	78	ND
23	SML-8B	Kairi	IM II	61	2623	110	13	25	ND	10	ND	258	ND
24	SML-8C	Kairi	BW(PS)	183	258	85	15	14	8	35	17	44	ND
25	SML-9A	Chandenamal	HP	14	272	1754	25	54	17	37	46	112	ND
26	SML-9B	Chandenamal	IM II	30	85	115	5	45	24	27	21	246	ND
27	SML-9C	Chandenamal	BW(PS)	122	3208	75	4	60	4	29	7	82	ND
28	SML-10A	Dabheri	HP	9	4468	197	8	ND	17	49	31	98	ND
29	SML-10B	Dabheri	IM II	30	85	31	3	ND	17	64	16	236	ND
30	SML-10C	Dabheri	TW	61	25	112	5	ND	ND	77	11	95	ND
31	SML-11A	Jalalabad	HP	21	2049	241	11	ND	2	48	13	85	ND
32	SML-11B	Jalalabad	IM II	34	1205	382	7	25	25	82	35	265	ND
33	SML-11C	Jalalabad	BW(PS)	98	2338	307	9	56	9	78	41	48	ND
34	SML-12A	Harad Fatehpur	HP	27	1976	300	5	63	11	23	27	98	ND
35	SML-12B	Harad Fatehpur	IM II	61	1953	139	19	73	44	54	ND	210	ND
36	SML-12C	Harad Fatehpur	TW	76	37	151	4	42	8	29	1	76	ND
37	SML-13A	Raipur	HP	24	4398	647	444	67	8	192	20	104	ND
38	SML-13B	Raipur	IM II	55	183	46	24	1	ND	15	3	256	ND
39	SML-13C	Raipur	TW	61	26	46	5	13	34	ND	13	92	ND
40	SML-14A	Masavi	HP	24	3320	269	7	19	31	5.0	22	135	ND
41	SML-14B	Masavi	IM II	40	283	182	8	14	40	ND	47	270	ND
		Minimum			25	27	1	ND	ND	ND	ND	21	ND
		Maximum			9830	1754	444	73	46	192	47	270	ND
		Mean			2055	203	23	35	23	52	16	131	ND

4.2.4 District Meerut

Total 16 ground water samples from private hand pumps, IM II hand pumps and tube wells were collected from 5 villages in the buffer zone of 2 km on the banks of Rivers Hindon and Kali falling in District Meerut (Fig. 4.8) and the results (Tables 4.14 to 4.16) have been discussed in the following sections.

General Characteristics

The pH values in the ground water samples collected from District Meerut fall within the range of 7.0 to 7.4 in private hand pumps, 7.0 to 7.6 in IM II hand pumps and 7.2 to 7.6 in tube wells. The pH values for all of the samples are well within the limits prescribed by BIS (2012) for various uses of water including drinking and other domestic supplies.

The electrical conductivity and dissolved salt concentrations are directly related to the concentration of ionized substance in water and may also be related to problems of excessive hardness and/or other mineral contamination. The conductivity values in the ground water samples vary from 560 to 1661 μS/cm in private hand pumps, 540 to 992 μS/cm in IM II hand pumps and 573 to 964 μS/cm in tube wells. The conductivity values above 1000 μS/cm was observed in private hand pumps of Dhilaura, Nahli and Pithlokar with maximum conductivity value of 1661 μS/cm in the hand pump of village Dhilaura.

The TDS value in the ground water samples collected from District Meerut varies from 358 to 1063 mg/L in private hand pumps, 346 to 635 mg/L in IM II hand pumps and 367 to 617 mg/L in tube wells. TDS values above the acceptable limit of 500 mg/L were observed in ground water of Baparsi, Dhilaura, Nahli and Pithlokar. Water containing more than 500 mg/L of TDS is not considered acceptable for drinking water supplies, though more highly mineralized water is also used where better water is not available. For this reason, 500 mg/L as the acceptable limit and 2000 mg/L as the permissible limit has been suggested for drinking water (BIS, 2012). None of the collected samples from District Meerut exceeded the permissible limit of 2000 mg/L. Water containing TDS more than 500 mg/L causes gastrointestinal irritation.

Alkalinity in natural water is mainly due to presence of carbonates, bicarbonates and hydroxides. Bicarbonates represent the major form since they are formed in considerable amount from the action of carbonates upon the basic materials in the soil. The alkalinity value in the collected samples from District Meerut varies from 201 to 428 mg/L in private hand pumps, 204 to 318 mg/L in IM II hand pumps and 210 to 312 mg/L in tube wells. All of the samples collected from private hand pumps, IM II hand pumps and tube wells exceeded the acceptable limit of 200 mg/L but within the permissible limit of 600 mg/L.

Hardness of water is due to carbonates, sulphates and chlorides of calcium and magnesium. A limit of 200 mg/L as acceptable limit and 600 mg/L as permissible limit has been recommended for drinking water (BIS, 2012). The total hardness values in the samples collected from District Meerut range from 136 to 423 mg/L in private hand pumps, 122 to 342 mg/L in IM II hand pumps and 144 to 308 mg/L in tube wells. None of the ground water sample collected from District Meerut exceeds the permissible limit of 600 mg/L.

In ground water of the samples collected from District Meerut, the values of calcium range from 25 to 84 mg/L in private hand pumps, 24 to 91 mg/L in IM II hand pumps and 28 to 59 mg/L in tube wells and the values of magnesium range from 10 to 52 mg/L in private hand pumps, 15 to 36 mg/L in IM II hand pumps and 18 to 39 mg/L in tube wells. The acceptable limit for calcium and magnesium for drinking water are 75 and 30 mg/L respectively (BIS, 2012). In ground water, the calcium content generally exceeds the magnesium content in accordance with their relative abundance in rocks. All ground water samples collected from District Meerut fall within the permissible limit of 200 mg/L of calcium and 100 mg/L of magnesium.

The concentration of sodium in the the samples collected from District Meerut varies from 17 to 162 mg/L in private hand pumps, 12 to 108 mg/L in IM II hand pumps and 26 to 50 mg/L in tube wells. The Bureau of Indian Standards has not included sodium in drinking water standards. The high sodium values in the collected samples may be attributed to base-exchange phenomena and causes sodium hazard. Ground water with such high sodium is not suitable for irrigation purpose.

Potassium is an essential element for humans, plants and animals and derived in food chain mainly from vegetation and soil. The main sources of potassium in ground water include rain water, weathering of potash silicate minerals, use of potash fertilizers and use of surface water for irrigation. The concentration of potassium in the ground water samples collected from District Meerut varies from 4.2 to 16 mg/L in private hand pumps, 4.0 to 8.0 mg/L in IM II hand pumps and 4.6 to 11 mg/L in tube wells. The Bureau of Indian Standards has not included potassium in drinking water standards. However, the European Economic Community has prescribed guideline level of potassium at 10 mg/L in drinking water. As per EEC criteria, the ground water samples collected from private hand pump and tube well of Dhilaura exceed the guideline level of 10 mg/L.

The concentration of chloride in the samples collected from District Meerut varies from 4.0 to 138 mg/L in private hand pumps, 4.0 to 50 mg/L in IM II hand pumps and 4.0 to 36 mg/L in tube wells. All samples were observed within the acceptable limit of 250 mg/L. The limits of chloride have been laid down primarily from taste considerations. A limit of 250 mg/L chloride has been recommended as acceptable limit and 1000 mg/L as the permissible limit for drinking water (BIS, 2012). However, no adverse health effects on humans have been reported from intake of waters containing even higher content of chloride. The concentration of sulphate in the samples collected from District Meerut varies from 2.5 to 4.0 mg/L in private hand pumps, 2.5 to 41 mg/L in IM II hand pumps and 2.5 to 12 mg/L in tube wells. Bureau of Indian standard has prescribed 200 mg/L as the acceptable limit and 400 mg/L as the permissible limit for sulphate in drinking water. In the samples collected from District Meerut, none of the samples exceeded the acceptable limit of 200 mg/L.

Nitrate content in drinking water is considered important for its adverse health effects and moderately toxicity. A limit of 45 mg/L has been prescribed by BIS (2012) for drinking water supplies. Its concentration above 45 mg/L may prove detriment to human health. In higher concentrations, nitrate may produce a disease known as methaemoglobinaemia (blue babies) which generally affects bottle-fed infants. Repeated heavy doses of nitrates on ingestion may also cause carcinogenic diseases. The nitrate content in the samples collected from District Meerut varies from 7.4 to 119 mg/L in private hand pumps, 4.2 to 18 mg/L in IM II hand pumps and 4.3 to 35 mg/L in tube wells. The nitrate concentration was observed more than permissible limit of 45 mg/L in ground water samples from private hand pumps of village Dhilaura and Pithlokar, which may be attributed to contamination by industrial/domestic waste disposal.

The presence of fluoride in ground water may be attributed to the localized effects of natural sources. The fluoride is present in soil strata due to the presence of geological formations like fluorspar, fluorapatite, ampheboles such as hornblinde, trimolite and mica. Weathering of alkali, silicate, igneous and sedimentary rocks specially shales contribute a major portion of fluorides to ground waters. In addition to natural sources, considerable amount of fluorides may be contributed due to man's activities. Fluoride salts are commonly used in steel, aluminium, bricks and tile-industries. The fluoride containing insecticides and herbicides may be contributed through agricultural runoff. Phosphatic fertilizers, which are extensively used, often contain fluorides as impurity and these may increase levels of fluoride in soil. The accumulation of fluoride in soil eventually results in its leaching due to percolating water, thus increase fluoride concentration in ground water. The fluoride content in the ground water samples collected from District Meerut varies from ND to 0.56 mg/L in private hand pumps, ND to 0.62 mg/L in IM II hand pumps and ND to 0.35 mg/L in tube wells. Ground water samples collected from all villages of the District Meerut fall within the acceptable limit of 1.0 mg/L and none of the ground water samples exceeded the permissible limit of 1.5 mg/L.

From the above discussion, it is clearly evident that in the ground water samples collected from District Meerut, the concentration of total dissolved solids exceeds the acceptable limit of 500 mg/L in ground water of Baparsi, Dhilaura, Nahli and Pithlokar but none of the samples exceeds the permissible limit of 2000 mg/L. None of the samples exceeded the permissible limit of hardness. The concentration of nitrate exceeded the permissible limit in ground water samples collected from the hand pumps of Dhilaura and Pithlokar. The concentration of fluoride was observed within the acceptable limit in all the samples. The violation of BIS limit could not be ascertained for sodium and potassium as no permissible limit for these constituents has been prescribed in BIS drinking water specifications. On the basis of above results, it can be inferred that ground water from private hand pumps have the problem of TDS and nitrate specially in the area of Dhilaura and Pithlokar, which may be attributed to possible impact of effluents discharged into river Hindon and Kali on the ground water.

Bacteriological Parameters

In water quality control technology, the principal indicator of suitability of water for domestic, industrial or other uses is the coliform group of bacteria. The density of coliform group is the criteria for the extent of contamination and has been the basis for bacteriological water quality standard. Further, the presence of faecal colifirms in water is the indicator of a potential public health problem, because faecal matter is a source of pathogenic bacteria and viruses. The faecal coliform bacteria contaminate water through percolation from contamination sources (domestic sewage and septic tank) and also because of poor sanitary system. The indiscriminate land disposal of domestic waste on surface and improper disposal of solid waste further aggravate the problem of bacterial contamination in water. The collected samples from District Meerut were analysed for bacteriological parameters viz; Total Coliform and Faecal Coliform. The result of bacteriological analysis is given in Table 4.15. The result shows that the bacterial contamination was observed in four ground water samples of four villages of the District Meerut.

Heavy Metals

Heavy metals in ground water have a considerable significance due to their toxicity and adsorption behaviour. Heavy metals are not biodegradable and enter the food chain through a number of pathways causing progressive toxicity due to the accumulation in human and animal organs during their life span on long term exposure to contaminated environments. Despite the presence of trace concentrations of Cr, Mn, Co, Cu and Zn in the aquatic environment, which is essential to a number of life processes, high concentrations of these metals become toxic. The major sources of heavy metals in ground water include weathering of rock minerals, discharge of sewage and other waste effluents on land and runoff water. The trace element data of ground water samples collected from the District Meerut is given in Table 4.16. The distribution of different metals is shown graphically in Fig. 4.9. The toxic effects of these elements and extent of their contamination in ground water is discussed in the following sections.

Iron (Fe): The concentration of iron in the ground water samples collected from District Meerut ranges from 0.396 to 3.619 mg/L in private hand pumps, 0.135 to 5.908 mg/L in IM II hand pumps and 0.035 to 2.150 mg/L in tube wells. The Bureau of Indian Standards has recommended 0.3 mg/L as the acceptable limit for iron in drinking water (BIS, 2012). WHO has prescribed 0.3 mg/L as the acceptability threshold value for iron (WHO, 2011). It is evident from the results that about 100% samples of private hand pumps, 80% samples of IM II hand pumps and 20% of tube wells exceed the acceptable limit of 0.3 mg/L. Highest concentration of iron was observed in the ground water collected from IM II hand pump of Baparsi. The higher concentration of iron in the almost all ground water samples may be attributed to leaching of industrial wastes flowing into the river Hindon and Kali.

It is a known fact that iron in trace amounts is essential for nutrition. High concentrations of iron generally cause inky flavour, bitter and astringent taste to water. Well water containing soluble iron remain clear while pumped out, but exposure to air causes precipitation of iron due to oxidation, with a consequence of rusty colour and turbidity. The objection to iron in the distribution system is not due to health reason but to staining of laundry and plumbing fixtures and appearance. Taste and order problems may be caused by filamentous organism that prey on iron compounds (frenothrix, gallionella and leptothrix are called iron bacteria), originating another consumer's objection (red water). The presence of iron bacteria may clog well screens or develop in the distribution system, particularly when sulphate compounds in addition to iron may be subjected to chemical reduction.

Manganese (Mn): The concentration of manganese in the ground water samples collected from District Meerut ranges from 0.027 to 0.130 mg/L in private hand pumps, 0.013 to 0.146 mg/L in IM II hand pumps and 0.015 to 0.127 mg/L in tube wells. Manganese is an essential trace nutrient for plants and animals, which does not occur naturally as a metal but is found in various salts and minerals frequently in association with iron compounds. Manganese may gain entry into the body by inhalation, consumption of food and through drinking water. A concentration of 0.1 mg/L has been recommended as an acceptable limit and 0.3 mg/L as the permissible limit for drinking water (BIS, 2012). WHO has prescribed 0.1 mg/L as the acceptability threshold value and 0.4 mg/L as health based value (WHO, 2011). It is evident from the results that more than 60% of the samples collected each from the private hand pumps, IM II hand pumps and tube wells fall within the acceptable limit of 0.1 mg/L and none of the samples exceeds the maximum permissible limit of 0.3 mg/L. The presence of manganese above permissible limit of drinking water often imparts alien taste to water. It also has adverse effects on domestic uses and water supply structures.

Copper (Cu): The concentration of copper in the ground water samples collected from District Meerut ranges from 0.012 to 0.177 mg/L in private hand pumps, 0.010 to 0.014 mg/L in IM II hand pumps and 0.007 to 0.011 mg/L in tube wells. The Bureau of Indian Standards has recommended 0.05 mg/L as the acceptable limit and 1.5 mg/L as the permissible limit in the absence of alternate source (BIS, 2012). Beyond 0.05 mg/L the water imparts astringent taste and cause discoloration and corrosion of pipes, fittings and utensils. World Health Organization has recommended 2.0 mg/L as the provisional guideline value for drinking purpose (WHO, 2011). In the present investigation, one sample collected from private hand pump of village Nahli of the District Meerut exceed the acceptable limit of 0.05 mg/L.

Nickel (Ni): The concentration of nickel in the ground water samples collected from District Meerut ranges from 0.002 to 0.071 mg/L in private hand pumps, ND to 0.052 mg/L in IM II hand pumps and ND to 0.022 mg/L in tube wells. The Bureau of Indian Standards has recommended 0.02 mg/L as the acceptable limit (BIS, 2012). World Health Organization has recommended 0.07 mg/L as the guideline value for drinking purposes (WHO, 2011). In this range it is not harmful in drinking water. About 80%, 67% and 40% of samples each from private hand pumps, IM II hand pumps and tube wells exceed the BIS limit of 0.02 mg/L.

Chromium (Cr): The concentration of chromium in the ground water samples collected from District Meerut ranges from 0.026 to 0.153 mg/L in private hand pumps, 0.007 to 0.130 mg/L in IM II hand pumps and ND to 0.114 mg/L in tube wells. A concentration of 0.05 mg/L has been recommended as an acceptable limit for drinking water (BIS, 2012). WHO has also prescribed 0.05 mg/L as the guideline value for drinking water (WHO, 2011). About 80%, 33% and 20% of samples each from private hand pumps, IM II hand pumps and tube wells exceed the BIS limit of 0.05 mg/L.

Hexavalent chromium has a deleterious effect on the liver, kidney, and respiratory organs with hemorrhagic effects, dermatitis, and ulceration of the skin for chronic and subchronic exposure. Municipal wastewater release considerable amount of chromium into the environment. In the natural environment, Cr(+6) is likely to be reduced to Cr(+3), thereby reducing the toxic impact of chromium discharges. The pathways of chromium contribution to ground water are that the chromium containing industrial effluent discharged into stream, the hexavalent state chromium may be reduced to trivalent state and later adsorbed on the suspended particulate. In case, it could not be adsorbed, the chromium remain in the form of colloidal suspension, may precipitate and become part of stream sediment, from where it may reach to ground water through percolation containing shallow aquifers.

Lead (Pb): In the ground water samples collected from District Meerut, the concentration of lead ranges from ND to 0.087 mg/L in private hand pumps, ND to 0.065 mg/L in IM II hand pumps and ND to 0.054 mg/L in tube wells. The Bureau of Indian Standards has prescribed 0.01 mg/L lead as the desirable limit for drinking water (BIS, 2012). Beyond this limit, the water becomes toxic. WHO has also prescribed 0.01 mg/L as guideline value for drinking water (WHO, 2011). About 40%, 80% and 80% of samples each from private hand pumps, IM II hand pumps and tube wells exceed the BIS limit of 0.01 mg/L.

Lead is not considered an essential nutritional element and is a cumulative poison to humans. Acute lead poisoning is extremely rare. The typical symptoms of advanced lead poisoning are constipation, anemia, gastrointestinal disturbance, tenderness and gradual paralysis in muscles, specifically arms with possible cases of lethargy and moroseness. The major source of lead contamination is the combustion of fossil fuel. Lead is removed from the atmosphere by rain and falls back on the earth surface and seeps into the ground. Lead passes from the soil to water and to the plants and finally into the food chain. In drinking water it occurs primarily due to corrosion of lead pipes and solders, especially in areas of soft water. It may be noted that the use of soft water of slightly acidic pH and the use of lead pipes in service and domestic water lines may provide higher concentrations of lead at the consumers's tap, particularly when the water use is minimal in the household (overnight still water in pipes).

Cadmium (Cd): In the ground water samples collected from District Meerut, the concentration of cadmium ranges from 0.004 to 0.019 mg/L in private hand pumps, 0.002 to 0.021 mg/L in IM II hand pumps and 0.004 to 0.017 mg/L in tube wells. The Bureau of Indian Standards has prescribed 0.003 mg/L cadmium as the acceptable limit for drinking water (BIS, 2012). Beyond this limit, the water becomes toxic. WHO has also prescribed 0.003 mg/L cadmium as the guideline value for drinking water (WHO, 2011). The drinking water having more than 3 μg/L of cadmium can cause bronchitis, emphysema, anaemia and renal stone formation in animals. All samples from private hand pumps and tube wells and about 80% samples from IM II hand pumps exceed the BIS limit of 0.003 mg/L.

Zinc (Zn): The concentration of zinc in the ground water samples collected from District Meerut ranges from 0.045 to 0.264 mg/L in private hand pumps, 0.128 to 0.228 mg/L in IM II hand pumps and 0.062 to 0.112 mg/L in tube wells. The Bureau of Indian Standards has prescribed 5.0 mg/L zinc as the acceptable limit and 15 mg/L as the permissible limit for drinking water (BIS, 2012). WHO has prescribed 3.0 mg/L as the guideline value for drinking water (WHO, 2011). All the samples were found within the desirable limit prescribed by BIS (2012) and WHO (2011).

Arsenic (As): In the ground water samples collected from District Meerut, the concentration of arsenic was not detected. Ground water is expected to contain higher arsenic concentrations than surface water. Because of its presence in geological materials, arsenic can be traced in water as originated by natural processes or by industrial activities – industrial waste, arsenical pesticides and smelting operations. Generally, arsenic found in two state – As(III) and As(V) in ground water. As(III) compounds are more toxic than As(V) compounds. Arsenic compounds are skin and lung carcinogens in humans. The Bureau of Indian Standards has prescribed 0.01 mg/L arsenic as the acceptable limit and 0.05 mg/L as the permissible limit for drinking water (BIS, 2012). Beyond this limit, the water becomes toxic. WHO has prescribed 0.01 mg/L arsenic as the guideline value for drinking water (WHO, 2011). In the present investigation, all the ground water samples collected from District Meerut were found within the acceptable limit prescribed by BIS (2012).

From the above results, it is quite clear that the presence of heavy metals has been recorded in many location and the water quality standards have been violated for iron (5 samples from private hand pumps, 5 samples from IM II hand pumps and 1 sample from tube wells), copper (1 sample from private hand pump), nickel (4 samples from private hand pumps, 4 samples from IM II hand pumps and 2 samples from tube wells), chromium (4 samples from private hand pumps, 2 samples from IM II hand pumps and 1 sample from tube wells), lead (2 samples from private hand pumps, 5 samples from IM II hand pumps and 4 samples from tube wells), Cadmium (5 samples each from private hand pumps, IM II hand pumps and tube wells) out of collected 5 samples each from private hand pumps and tube wells and 6 samples from IM II hand pumps of District Meerut.

Pesticides

The analysis of nine organo-chlorinated pesticides (Aldrin, α-BHC, β-BHC, γ-BHC, δ-BHC, DDD, DDE, Endosulphan and Methoxychlor) was carried out in ground water samples from IM II hand pump of Baparsi and Pithlokar of District Meerut but none of the pesticide has been detected in the analysed samples.

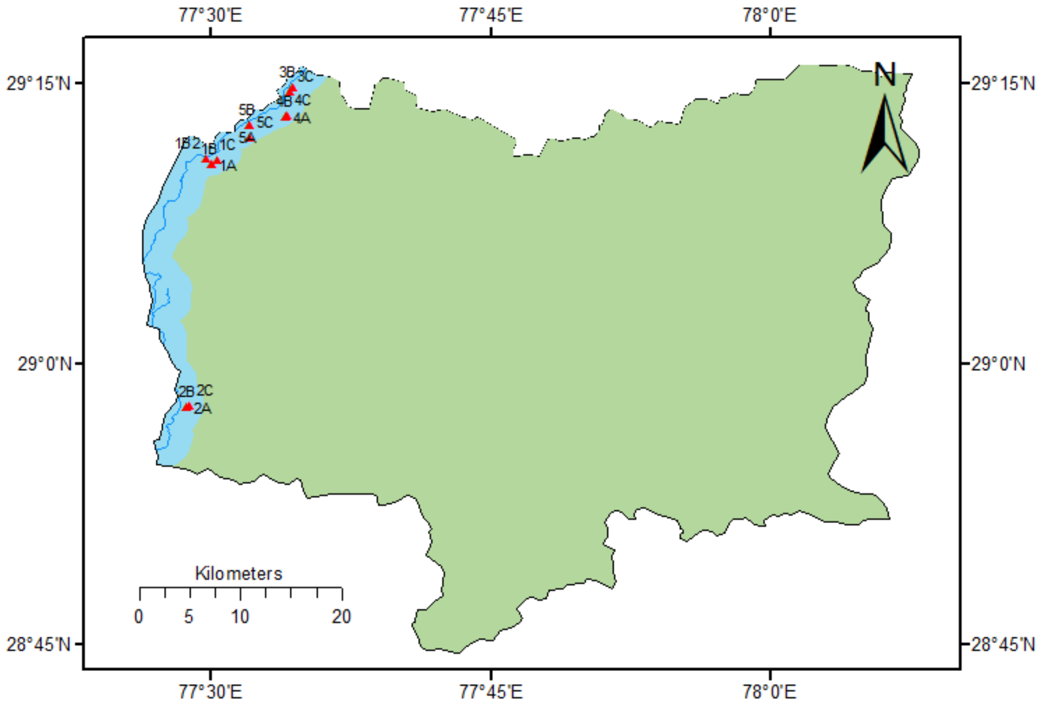


Fig. 4.8 Ground Water Sampling Locations in District Meerut in Two km Buffer Zone of River Hindon

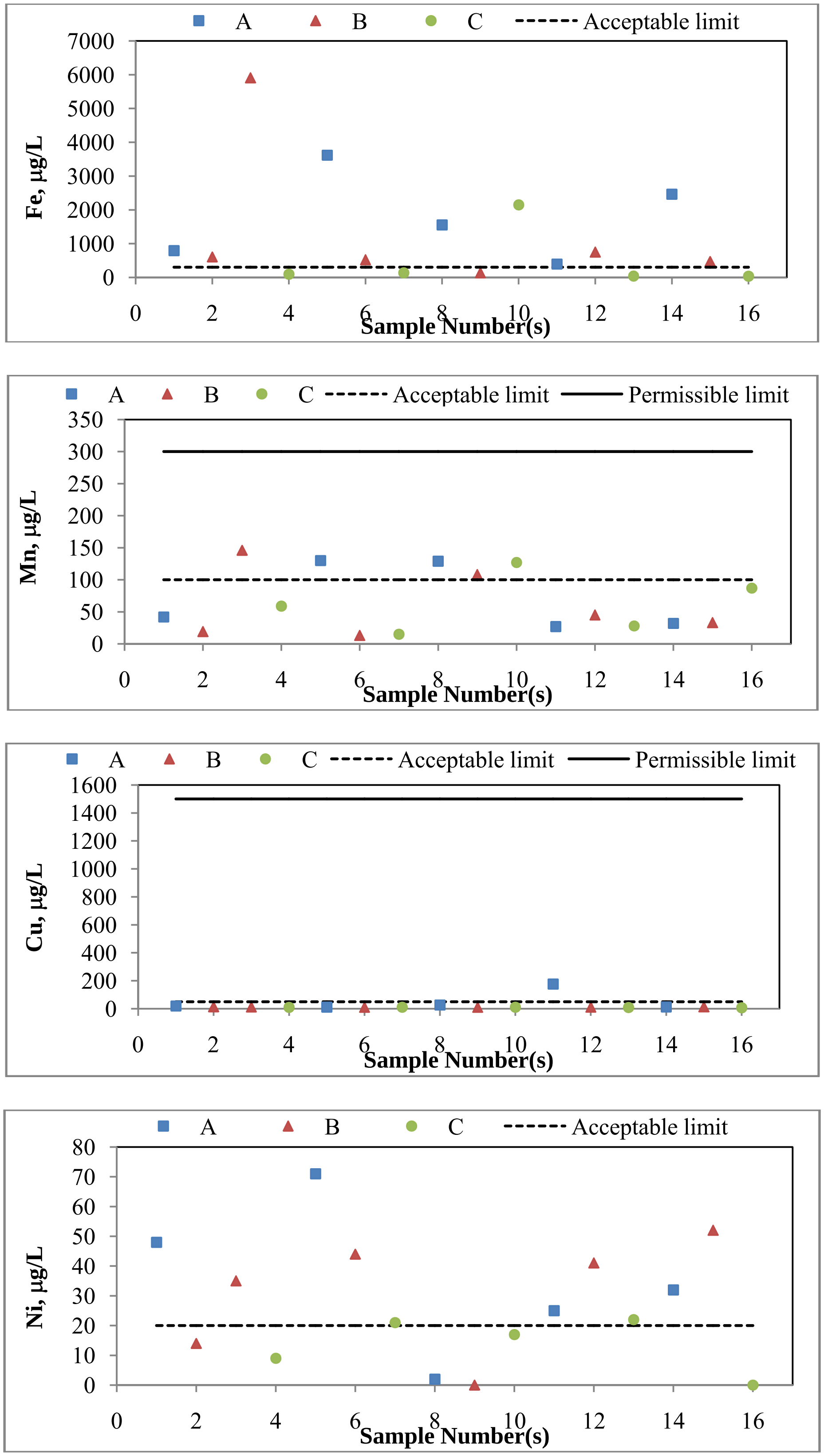
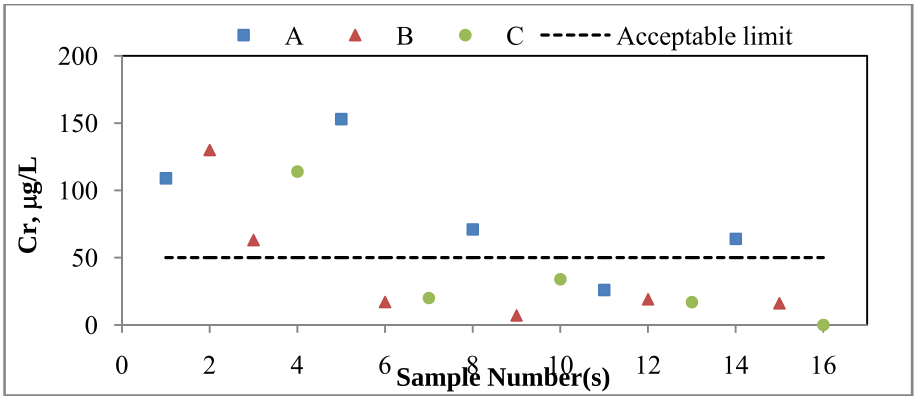
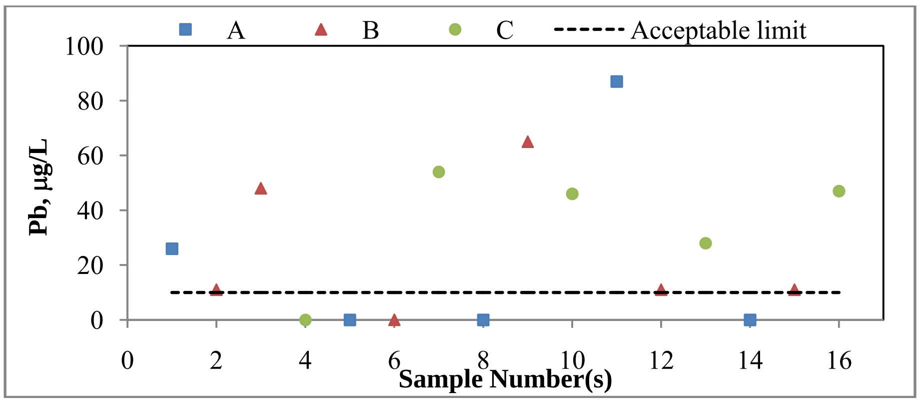
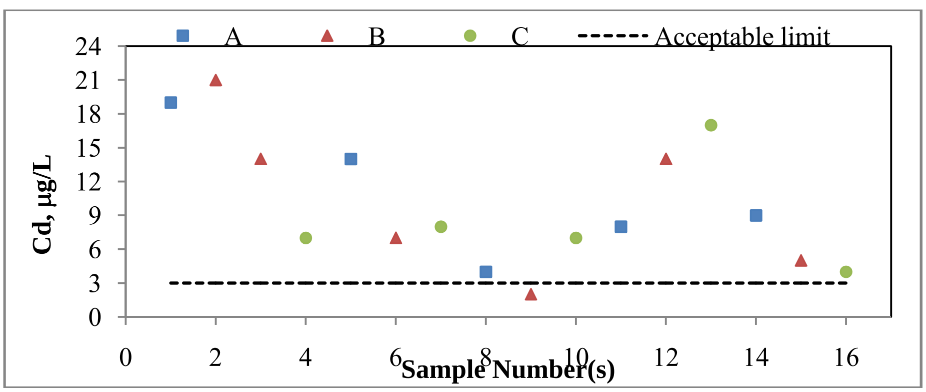


Fig. 4.9 Distribution of Trace Elements in Ground Water of District Meerut







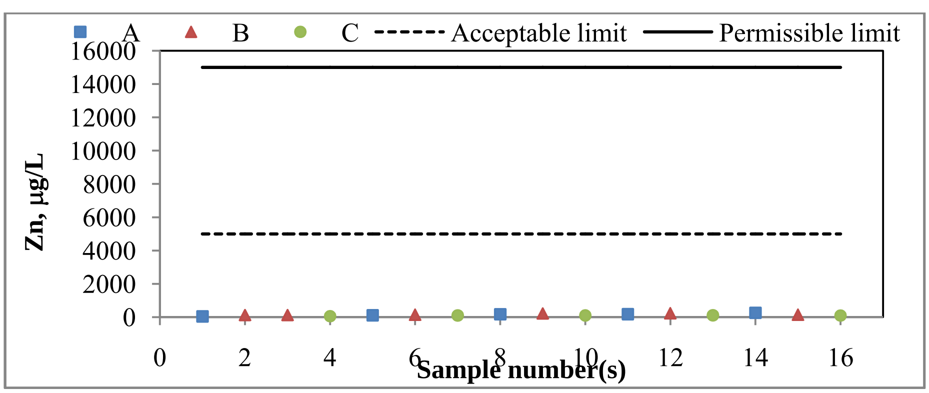


Fig. 4.9 (Contd.) Distribution of Trace Elements in Ground Water of District Meerut

Table 4.14 Hydro-chemical Data of Ground Water Samples of District Meerut (March 2013)

S.No.	Sample ID	Location	Source	Depth	pH	EC	TDS	Alk	Hard	Na	K	Ca	Mg	HCO3	Cl	SO4	NO3	PO4	F	BOD	COD
				m		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1	MTC-1A	Baparsi	HP	30	7.2	742	475	278	263	30	4.9	41	39	339	8	2.5	7.4	0.16	ND	1.2	4.4
2	MTC-1B	Baparsi	IM II	37	7.2	756	484	282	254	33	5.0	54	29	344	4	2.5	7.4	0.08	0.62	0.8	3.6
3	MTC-1B2	Baparsi	IM II	37	7.0	992	635	306	342	37	7.9	91	28	373	50	41	4.2	0.06	0.42	0.8	3.0
4	MTC-1C	Baparsi	TW	55	7.2	696	445	260	224	26	7.1	52	23	317	8	5.5	4.3	0.04	0.04	0.4	2.2
5	MTC-2A	Dhilaura	HP	9	7.4	1661	1063	406	423	153	16	84	52	495	138	2.5	119	0.12	ND	1.4	3.2
6	MTC-2B	Dhilaura	IM II	37	7.5	898	575	318	256	59	5.5	50	32	388	18	2.5	17	0.06	0.62	1.0	4.4
7	MTC-2C	Dhilaura	TW	15	7.6	964	617	312	308	50	11	59	39	381	36	2.5	35	0.06	0.06	1.2	4.5
8	MTC-3A	Alamgirpur Faridpur	HP	61	7.4	560	358	201	199	17	4.2	55	15	245	4	4.0	11	0.08	0.34	1.3	4.6
9	MTC-3B	Alamgirpur Faridpur	IM II	37	7.6	540	346	204	206	12	4.0	28	33	249	8	3.0	6.9	0.06	0.47	0.4	2.6
10	MTC-3C	Alamgirpur Faridpur	TW	12	7.3	642	411	210	158	48	4.6	32	19	256	16	12	21	0.06	0.23	0.6	2.1
11	MTC-4A	Nahli	HP	18	7.4	1180	755	428	136	162	4.5	25	18	522	6	2.5	10	0.08	0.56	0.8	3.0
12	MTC-4B	Nahli	IM II	37	7.4	875	560	308	122	108	5	24	15	376	8	3.5	18	0.06	ND	0.4	1.0
13	MTC-4C	Nahli	TW	67	7.3	573	367	210	144	38	5.6	28	18	256	4	5.0	10	0.04	0.35	0.2	1.2
14	MTC-5A	Pithlokar	HP	12	7.0	1455	931	408	291	162	9.5	69	29	498	100	2.5	57	0.06	ND	0.6	2.2
15	MTC-5B	Pithlokar	IM II	37	7.2	725	464	272	248	29	5.2	40	36	332	8	2.5	6.0	0.04	0.36	0.5	2.6
16	MTC-5C	Pithlokar	TW	49	7.5	670	429	232	224	33	5.9	42	29	283	24	2.5	6.9	0.02	ND	0.2	1.8
		Minimum			7.0	540	346	201	122	12	4.0	24	15	245	4.0	2.5	4.2	0.02	ND	0.2	1.0
		Maximum			7.6	1661	1063	428	423	162	16	91	52	522	138	41	119	0.16	0.62	1.4	4.6
		Mean			7.3	871	557	290	237	62	6.6	48	28	353	28	6.0	21	0.07	0.37	0.7	2.9

Table 4.15 Bacteriological Data of Ground Water Samples of District Meerut (March 2013)						
S.No.	**Sample ID**	**Location**	**Source**	**Depth**	**Total Coliform**	**Fecal Coliform**
				m	per 100 ml	per 100 ml
1	MTC-1A	Baparsi	HP	30	<3	<3
2	MTC-1B	Baparsi	IM II	37	<3	<3
3	MTC-1B2	Baparsi	IM II	37	<3	<3
4	MTC-1C	Baparsi	TW	55	<3	<3
5	MTC-2A	Dhilaura	HP	9	23	<3
6	MTC-2B	Dhilaura	IM II	37	<3	<3
7	MTC-2C	Dhilaura	TW	15	<3	<3
8	MTC-3A	Alamgirpur Faridpur	HP	61	<3	<3
9	MTC-3B	Alamgirpur Faridpur	IM II	37	<3	<3
10	MTC-3C	Alamgirpur Faridpur	TW	12	43	4
11	MTC-4A	Nahli	HP	18	150	<3
12	MTC-4B	Nahli	IM II	37	<3	<3
13	MTC-4C	Nahli	TW	67	<3	<3
14	MTC-5A	Pithlokar	HP	12	43	<3
15	MTC-5B	Pithlokar	IM II	37	<3	<3
16	MTC-5C	Pithlokar	TW	49	<3	<3

Table 4.16 Trace Element Data of Ground Water Samples of District Meerut (March 2013)

S.No.	Sample ID	Location	Source	Depth	Fe	Mn	Cu	Ni	Cr	Pb	Cd	Zn	As
				m	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
1	MTC-1A	Baparsi	HP	30	794	42	20	48	109	26	19	45	ND
2	MTC-1B	Baparsi	IM II	37	606	19	14	14	130	11	21	130	ND
3	MTC-1B2	Baparsi	IM II	37	5908	146	12	35	63	48	14	128	ND
4	MTC-1C	Baparsi	TW	55	94	59	10	9.0	114	ND	7.0	62	ND
5	MTC-2A	Dhilaura	HP	9	3619	130	12	71	153	ND	14	112	ND
6	MTC-2B	Dhilaura	IM II	37	520	13	10	44	17	ND	7.0	145	ND
7	MTC-2C	Dhilaura	TW	15	137	15	11	21	20	54	8.0	108	ND
8	MTC-3A	Alamgirpur Faridpur	HP	61	1555	129	27	2.0	71	ND	4.0	178	ND
9	MTC-3B	Alamgirpur Faridpur	IM II	37	135	108	10	ND	7.0	65	2.0	226	ND
10	MTC-3C	Alamgirpur Faridpur	TW	12	2150	127	11	17	34	46	7.0	106	ND
11	MTC-4A	Nahli	HP	18	396	27	177	25	26	87	8.0	182	ND
12	MTC-4B	Nahli	IM II	37	747	45	11	41	19	11	14	228	ND
13	MTC-4C	Nahli	TW	67	41	28	9.0	22	17	28	17	112	ND
14	MTC-5A	Pithlokar	HP	12	2463	32	13	32	64	ND	9.0	264	ND
15	MTC-5B	Pithlokar	IM II	37	472	33	13	52	16	11	5.0	146	ND
16	MTC-5C	Pithlokar	TW	49	35	87	7.0	ND	ND	47	4.0	101	ND
		Minimum			35	13	7.0	ND	ND	ND	2.0	45	ND
		Maximum			5908	146	177	71	153	87	21	264	ND
		Mean			1230	65	23	31	57	39	10	142	ND

4.2.5 District Baghpat

Total 15 ground water samples from private hand pumps, IM II hand pumps and bore wells/tube wells were collected from 6 villages in the buffer zone of 2 km on the banks of Rivers Hindon and Krishni falling in District Baghpat (Fig. 4.10) and the results (Tables 4.17 to 4.19) have been discussed in the following sections.

General Characteristics

The pH values in the ground water samples collected from District Baghpat fall within the range of 7.1 to 9.0 in private hand pumps, 7.3 to 7.8 in IM II hand pumps and 7.2 to 7.7 in bore wells/tube wells. The pH values for all of the samples except private hand pump of Gangnoli are well within the limits prescribed by BIS (2012) for various uses of water including drinking and other domestic supplies.

The electrical conductivity and dissolved salt concentrations are directly related to the concentration of ionized substance in water and may also be related to problems of excessive hardness and/or other mineral contamination. The conductivity values in the ground water samples vary from 665 to 1485 μS/cm in private hand pumps, 758 to 1371 μS/cm in IM II hand pumps and 915 to 1010 μS/cm in bore wells/tube wells. The conductivity above 1000 μS/cm was observed in private hand pumps of Khaprana, Galheta, Himmatpur and Barnawa, in IM II hand pumps of Khaprana, Bamnauli and Barnawa and in the tube well of Himmatpur with maximum conductivity value of 1485 μS/cm in the private hand pump of village Himmatpur.

The TDS value in the ground water samples collected from District Baghpat varies from 426 to 950 mg/L in private hand pumps, 485 to 877 mg/L in IM II hand pumps and 586 to 646 mg/L in bore wells/tube wells. TDS values above the acceptable limit of 500 mg/L were observed in all ground water samples except one private hand pump of village Gangnoli and one IM II hand pump of Galheta. Water containing more than 500 mg/L of TDS is not considered acceptable for drinking water supplies, though more highly mineralized water is also used where better water is not available. For this reason, 500 mg/L as the acceptable limit and 2000 mg/L as the maximum permissible limit has been suggested for drinking water (BIS, 2012). None of the collected samples from District Baghpat exceeded the permissible limit of 2000 mg/L. Water containing TDS more than 500 mg/L causes gastrointestinal irritation.

Alkalinity in natural water is mainly due to presence of carbonates, bicarbonates and hydroxides. Bicarbonates represent the major form since they are formed in considerable amount from the action of carbonates upon the basic materials in the soil. The alkalinity value in the collected samples from District Baghpat varies from 206 to 472 mg/L in private hand pumps, 202 to 332 mg/L in IM II hand pumps and 308 to 328 mg/L in bore wells/tube wells. All of the samples collected from private hand pumps, IM II hand pumps and bore wells/tube wells exceeded the acceptable limit of 200 mg/L but are within the permissible limit of 600 mg/L.

Hardness of water is due to carbonates, sulphates and chlorides of calcium and magnesium. A limit of 200 mg/L as acceptable limit and 600 mg/L as permissible limit has been recommended for drinking water (BIS, 2012). The total hardness values in the samples collected

from District Baghpat range from 74 to 362 mg/L in private hand pumps, 124 to 313 mg/L in IM II hand pumps and 159 to 199 mg/L in bore wells/tube wells. None of the ground water sample collected from District Baghpat crossed the permissible limit of 600 mg/L.

In ground water of the samples collected from District Baghpat, the values of calcium range from 13 to 76 mg/L in private hand pumps, 30 to 66 mg/L in IM II hand pumps and 26 to 37 mg/L in bore wells/tube wells and the values of magnesium range from 10 to 47 mg/L in private hand pumps, 12 to 36 mg/L in IM II hand pumps and 23 to 26 mg/L in bore wells/tube wells. The acceptable limit for calcium and magnesium for drinking water are 75 and 30 mg/L respectively (BIS, 2012). In ground water, the calcium content generally exceeds the magnesium content in accordance with their relative abundance in rocks. All ground water samples collected from District Baghpat fall within the permissible limit of 200 mg/L of calcium and 100 mg/L of magnesium.

The concentration of sodium in the the samples collected from District Baghpat varies from 96 to 170 mg/L in private hand pumps, 95 to 168 mg/L in IM II hand pumps and 104 to 110 mg/L in bore wells/tube wells. The Bureau of Indian Standards has not included sodium in drinking water standards. The high sodium values in the collected samples may be attributed to base-exchange phenomena and causes sodium hazard. Ground water with such high sodium is not suitable for irrigation purpose.

Potassium is an essential element for humans, plants and animals and derived in food chain mainly from vegetation and soil. The main sources of potassium in ground water include rain water, weathering of potash silicate minerals, use of potash fertilizers and use of surface water for irrigation. The concentration of potassium in the ground water samples collected from District Baghpat varies from 4.4 to 8.0 mg/L in private hand pumps, 4.0 to 5.9 mg/L in IM II hand pumps and 4.3 to 6.8 mg/L in bore wells/tube wells. The Bureau of Indian Standards has not included potassium in drinking water standards. However, the European Economic Community has prescribed guideline level of potassium at 10 mg/L in drinking water. As per EEC criteria, all the ground water samples collected from District Baghpat fall within the guideline level of 10 mg/L.

The concentration of chloride in the samples collected from District Baghpat varies from 30 to 60 mg/L in private hand pumps, 20 to 120 mg/L in IM II hand pumps and 14 to 32 mg/L in bore wells/tube wells. All samples were observed within the acceptable limit of 250 mg/L. The limits of chloride have been laid down primarily from taste considerations. A limit of 250 mg/L chloride has been recommended as acceptable limit and 1000 mg/L as the permissible limit for drinking water (BIS, 2012). However, no adverse health effects on humans have been reported from intake of waters containing even higher content of chloride. The concentration of sulphate in the samples collected from District Baghpat varies from 5.0 to 50 mg/L in private hand pumps, 5.0 to 35 mg/L in IM II hand pumps and 7.0 to 45 mg/L in bore wells/tube wells. Bureau of Indian standard has prescribed 200 mg/L as the acceptable limit and 400 mg/L as the permissible limit for sulphate in drinking water. In the samples collected from District Baghpat, none of the samples exceeded the maximum acceptable limit of 200 mg/L.

Nitrate content in drinking water is considered important for its adverse health effects and moderately toxicity. A limit of 45 mg/L has been prescribed by BIS (2012) for drinking water supplies. Its concentration above 45 mg/L may prove detriment to human health. In higher concentrations, nitrate may produce a disease known as methaemoglobinaemia (blue babies) which generally affects bottle-fed infants. Repeated heavy doses of nitrates on ingestion may also cause carcinogenic diseases. The nitrate content in the samples collected from District Baghpat varies from 2.6 to 94 mg/L in private hand pumps, 0.6 to 220 mg/L in IM II hand pumps and 1.8 to 7.0 mg/L in bore wells/tube wells. The nitrate concentration was observed more than permissible limit of 45 mg/L in ground water samples from private hand pumps of village Khaprana, Galheta and Barnawa and IM II hand pump of Khaprana, which may be attributed to contamination by industrial/domestic waste disposal.

The presence of fluoride in ground water may be attributed to the localized effects of natural sources. The fluoride is present in soil strata due to the presence of geological formations like fluorspar, fluorapatite, ampheboles such as hornblinde, trimolite and mica. Weathering of alkali, silicate, igneous and sedimentary rocks specially shales contribute a major portion of fluorides to ground waters. In addition to natural sources, considerable amount of fluorides may be contributed due to man's activities. Fluoride salts are commonly used in steel, aluminium, bricks and tile-industries. The fluoride containing insecticides and herbicides may be contributed through agricultural runoff. Phosphatic fertilizers, which are extensively used, often contain fluorides as impurity and these may increase levels of fluoride in soil. The accumulation of fluoride in soil eventually results in its leaching due to percolating water, thus increase fluoride concentration in ground water. The fluoride content in the ground water samples collected from District Baghpat varies from ND to 1.53 mg/L in private hand pumps, 0.02 to 0.72 mg/L in IM II hand pumps and 0.52 to 0.71 mg/L in bore wells/tube wells. Ground water samples collected from private hand pumps of villages Khaprana and Galheta exceed the acceptable limit of 1.0 mg/L while the sample from Khaprana even exceeds the maximum permissible limit of 1.5 mg/L.

From the above discussion, it is clearly evident that in the ground water samples collected from District Baghpat, the concentration of total dissolved solids was observed above the acceptable limit of 500 mg/L in almost all the ground water samples collected from District Baghpat but none of the samples exceeded the maximum permissible limit of 2000 mg/L. None of the samples exceeded the maximum permissible limit of hardness of 600 mg/L. The concentration of nitrate exceeded the permissible limit in ground water samples collected from the private hand pumps of village Khaprana, Galheta and Barnawa and IM II hand pump of Khaprana,. The concentration of fluoride was observed to exceed the acceptable limit in ground water of villages Khaprana and Galheta. The violation of BIS limit could not be ascertained for sodium and potassium as no permissible limit for these constituents has been prescribed in BIS drinking water specifications. On the basis of above results, it can be inferred that ground water from private hand pumps have the problem of TDS and nitrate specially in the area of Khaprana, Galheta and Barnawa, which may be attributed to possible impact of effluents discharged into river Hindon and Krishni on the ground water.

Bacteriological Parameters

In water quality control technology, the principal indicator of suitability of water for domestic, industrial or other uses is the coliform group of bacteria. The density of coliform group is the criteria for the extent of contamination and has been the basis for bacteriological water quality standard. Further, the presence of faecal colifirms in water is the indicator of a potential public health problem, because faecal matter is a source of pathogenic bacteria and viruses. The faecal coliform bacteria contaminate water through percolation from contamination sources (domestic sewage and septic tank) and also because of poor sanitary system. The indiscriminate land disposal of domestic waste on surface and improper disposal of solid waste further aggravate the problem of bacterial contamination in water. The collected samples from District Baghpat were analysed for bacteriological parameters viz; Total Coliform and Faecal Coliform. The result of bacteriological analysis is given in Table 4.18. The result shows that the bacterial contamination was observed in three ground water samples of six villages of District Baghpat.

Heavy Metals

Heavy metals in ground water have a considerable significance due to their toxicity and adsorption behaviour. Heavy metals are not biodegradable and enter the food chain through a number of pathways causing progressive toxicity due to the accumulation in human and animal organs during their life span on long term exposure to contaminated environments. Despite the presence of trace concentrations of Cr, Mn, Co, Cu and Zn in the aquatic environment, which is essential to a number of life processes, high concentrations of these metals become toxic. The major sources of heavy metals in ground water include weathering of rock minerals, discharge of sewage and other waste effluents on land and runoff water. The trace element data of ground water samples collected from the District Baghpat is given in Table 4.19. The distribution of different metals is shown graphically in Fig. 4.11. The toxic effects of these elements and extent of their contamination in ground water is discussed in the following sections.

Iron (Fe): The concentration of iron in the ground water samples collected from District Baghpat ranges from 0.062 to 24.828 mg/L in private hand pumps, 0.273 to 2.691 mg/L in IM II hand pumps and 0.059 to 17.235 mg/L in bore wells/tube wells. The Bureau of Indian Standards has recommended 0.3 mg/L as the acceptable limit for iron in drinking water (BIS, 2012). WHO has prescribed 0.3 mg/L as the acceptability threshold value for iron (WHO, 2011). It is evident from the results that about 80% samples each from private hand pumps and IM II hand pumps and 67% of bore wells/tube wells exceed the acceptable limit of 0.3 mg/L. Highest concentration of iron was observed in the ground water collected from private hand pump of Gangnoli. The higher concentration of iron in the almost all ground water samples may be attributed to leaching of industrial wastes flowing into the river Hindon and Krishni.

It is a known fact that iron in trace amounts is essential for nutrition. High concentrations of iron generally cause inky flavour, bitter and astringent taste to water. Well water containing soluble iron remain clear while pumped out, but exposure to air causes precipitation of iron due to oxidation, with a consequence of rusty colour and turbidity. The objection to iron in the distribution system is not due to health reason but to staining of laundry and plumbing fixtures and appearance. Taste and order problems may be caused by filamentous organism that prey on iron compounds (frenothrix, gallionella and leptothrix are called iron bacteria), originating another consumer's objection (red water). The presence of iron bacteria may clog well screens or develop in the distribution system, particularly when sulphate compounds in addition to iron may be subjected to chemical reduction.

Manganese (Mn): The concentration of manganese in the ground water samples collected from District Baghpat ranges from 0.088 to 0.280 mg/L in private hand pumps, 0.022 to 0.339 mg/L in IM II hand pumps and 0.012 to 0.125 mg/L in bore wells/tube wells. Manganese is an essential trace nutrient for plants and animals, which does not occur naturally as a metal but is found in various salts and minerals frequently in association with iron compounds. Manganese may gain entry into the body by inhalation, consumption of food and through drinking water. A concentration of 0.1 mg/L has been recommended as an acceptable limit and 0.3 mg/L as the permissible limit for drinking water (BIS, 2012). WHO has prescribed 0.1 mg/L as the acceptability threshold value and 0.4 mg/L as health based value (WHO, 2011). It is evident from the results that more than 50% of the samples collected each from the private hand pumps and IM II hand pumps and bore wells/tube wells fall within the acceptable limit of 0.1 mg/L and only one of the samples from IM II hand pump of Khaprana exceeds the maximum permissible limit of 0.3 mg/L. The presence of manganese above permissible limit of drinking water often imparts alien taste to water. It also has adverse effects on domestic uses and water supply structures.

Copper (Cu): The concentration of copper in the ground water samples collected from District Baghpat ranges from 0.003 to 0.026 mg/L in private hand pumps, 0.003 to 0.011 mg/L in IM II hand pumps and 0.003 to 0.010 mg/L in bore wells/tube wells. The Bureau of Indian Standards has recommended 0.05 mg/L as the acceptable limit and 1.5 mg/L as the permissible limit in the absence of alternate source (BIS, 2012). Beyond 0.05 mg/L the water imparts astringent taste and cause discoloration and corrosion of pipes, fittings and utensils. World Health Organization has recommended 2.0 mg/L as the provisional guideline value for drinking purpose (WHO, 2011). In the present investigation, none of the samples collected from the District Baghpat exceeds the acceptable limit of 0.05 mg/L.

Nickel (Ni): The concentration of nickel in the ground water samples collected from District Baghpat ranges from ND to 0.084 mg/L in private hand pumps, 0.003 to 0.052 mg/L in IM II hand pumps and 0.001 to 0.040 mg/L in bore wells/tube wells. The Bureau of Indian Standards has recommended 0.02 mg/L as the acceptable limit (BIS, 2012). World Health Organization has recommended 0.07 mg/L as the guideline value for drinking purposes (WHO, 2011). In this range it is not harmful in drinking water. About 66%, 50% and 66% of samples each from private hand pumps, IM II hand pumps and bore wells/tube wells respectively exceed the BIS limit of 0.02 mg/L.

Chromium (Cr): The concentration of chromium in the ground water samples collected from District Baghpat ranges from 0.003 to 0.129 mg/L in private hand pumps, ND to 0.103 mg/L in IM II hand pumps and 0.039 to 0.134 mg/L in bore wells/tube wells. A concentration of 0.05 mg/L has been recommended as an acceptable limit for drinking water (BIS, 2012). WHO has also prescribed 0.05 mg/L as the guideline value for drinking water (WHO, 2011). About

66%, 50% and 66% of samples each from private hand pumps, IM II hand pumps and bore wells/tube wells exceed the BIS limit of 0.05 mg/L.

Hexavalent chromium has a deleterious effect on the liver, kidney and respiratory organs with hemorrhagic effects, dermatitis, and ulceration of the skin for chronic and subchronic exposure. Municipal wastewater release considerable amount of chromium into the environment. In the natural environment, Cr(+6) is likely to be reduced to Cr(+3), thereby reducing the toxic impact of chromium discharges. The pathways of chromium contribution to ground water are that the chromium containing industrial effluent discharged into stream, the hexavalent state chromium may be reduced to trivalent state and later adsorbed on the suspended particulate. In case, it could not be adsorbed, the chromium remain in the form of colloidal suspension, may precipitate and become part of stream sediment, from where it may reach to ground water through percolation containing shallow aquifers.

Lead (Pb): In the ground water samples collected from District Baghpat, the concentration of lead ranges from 0.021 to 0.086 mg/L in private hand pumps, ND to 0.071 mg/L in IM II hand pumps and ND to 0.062 mg/L in bore wells/tube wells. The Bureau of Indian Standards has prescribed 0.01 mg/L lead as the desirable limit for drinking water (BIS, 2012). Beyond this limit, the water becomes toxic. WHO has also prescribed 0.01 mg/L as guideline value for drinking water (WHO, 2011). About 100%, 66% and 33% of samples each from private hand pumps, IM II hand pumps and bore wells/tube wells exceed the BIS limit of 0.01 mg/L.

Lead is not considered an essential nutritional element and is a cumulative poison to humans. Acute lead poisoning is extremely rare. The typical symptoms of advanced lead poisoning are constipation, anemia, gastrointestinal disturbance, tenderness and gradual paralysis in muscles, specifically arms with possible cases of lethargy and moroseness. The major source of lead contamination is the combustion of fossil fuel. Lead is removed from the atmosphere by rain and falls back on the earth surface and seeps into the ground. Lead passes from the soil to water and to the plants and finally into the food chain. In drinking water it occurs primarily due to corrosion of lead pipes and solders, especially in areas of soft water. It may be noted that the use of soft water of slightly acidic pH and the use of lead pipes in service and domestic water lines may provide higher concentrations of lead at the consumers’s tap, particularly when the water use is minimal in the household (overnight still water in pipes).

Cadmium (Cd): In the ground water samples collected from District Baghpat, the concentration of cadmium ranges from ND to 0.029 mg/L in private hand pumps, ND to 0.013 mg/L in IM II hand pumps and ND to 0.022 mg/L in bore wells/tube wells. The Bureau of Indian Standards has prescribed 0.003 mg/L cadmium as the acceptable limit for drinking water (BIS, 2012). Beyond this limit, the water becomes toxic. WHO has also prescribed 0.003 mg/L cadmium as the guideline value for drinking water (WHO, 2011). The drinking water having more than 3 μg/L of cadmium can cause bronchitis, emphysema, anaemia and renal stone formation in animals. About 66%, 33% and 66% samples each from private hand pumps, IM II hand pumps and bore wells/tube wells respectively exceed the BIS limit of 0.003 mg/L.

Zinc (Zn): The concentration of zinc in the ground water samples collected from District Baghpat ranges from 0.014 to 0.165 mg/L in private hand pumps, 0.090 to 0.256 mg/L in IM II hand pumps and 0.036 to 0.145 mg/L in bore wells/tube wells. The Bureau of Indian Standards has prescribed 5.0 mg/L zinc as the acceptable limit and 15 mg/L as the permissible limit for drinking water (BIS, 2012). WHO has prescribed 3.0 mg/L as the guideline value for drinking water (WHO, 2011). All the samples were found within the desirable limit prescribed by BIS (2012) and WHO (2011).

Arsenic (As): In the ground water samples collected from District Baghpat, the concentration of arsenic was not detected. Ground water is expected to contain higher arsenic concentrations than surface water. Because of its presence in geological materials, arsenic can be traced in water as originated by natural processes or by industrial activities – industrial waste, arsenical pesticides and smelting operations. Generally, arsenic found in two state – As(III) and As(V) in ground water. As(III) compounds are more toxic than As(V) compounds. Arsenic compounds are skin and lung carcinogens in humans. The Bureau of Indian Standards has prescribed 0.01 mg/L arsenic as the acceptable limit and 0.05 mg/L as the permissible limit for drinking water (BIS, 2012). Beyond this limit, the water becomes toxic. WHO has prescribed 0.01 mg/L arsenic as the guideline value for drinking water (WHO, 2011). In the present investigation, all the ground water samples collected from District Baghpat were found within the acceptable limit prescribed by BIS (2012).

From the above results, it is quite clear that the presence of heavy metals has been recorded in many location and the water quality standards have been violated for iron (5 samples from private hand pumps, 5 samples from IM II hand pumps and 2 samples from tube wells), manganese (1 sample from IM II hand pump), nickel (4 samples from private hand pumps, 3 samples from IM II hand pumps and 2 samples from bore wells/tube wells), chromium (4 samples from private hand pumps, 3 samples from IM II hand pumps and 2 samples from tube wells), lead (all samples from private hand pumps, 4 samples from IM II hand pumps and 1 sample from bore well), Cadmium (4 samples each from private hand pumps, 2 samples each from IM II hand pumps and tube wells) out of collected 6 samples each from private hand pumps and IM II hand pumps and 3 samples from bore wells/tube wells of District Baghpat.

Pesticides

The analysis of nine organo-chlorinated pesticides (Aldrin, α-BHC, β-BHC, γ-BHC, δ-BHC, DDD, DDE, Endosulphan and Methoxychlor) was carried out in ground water samples from IM II hand pump of Khaprana and Barnawa of District Baghpat but none of the pesticide has been detected in the analysed samples.

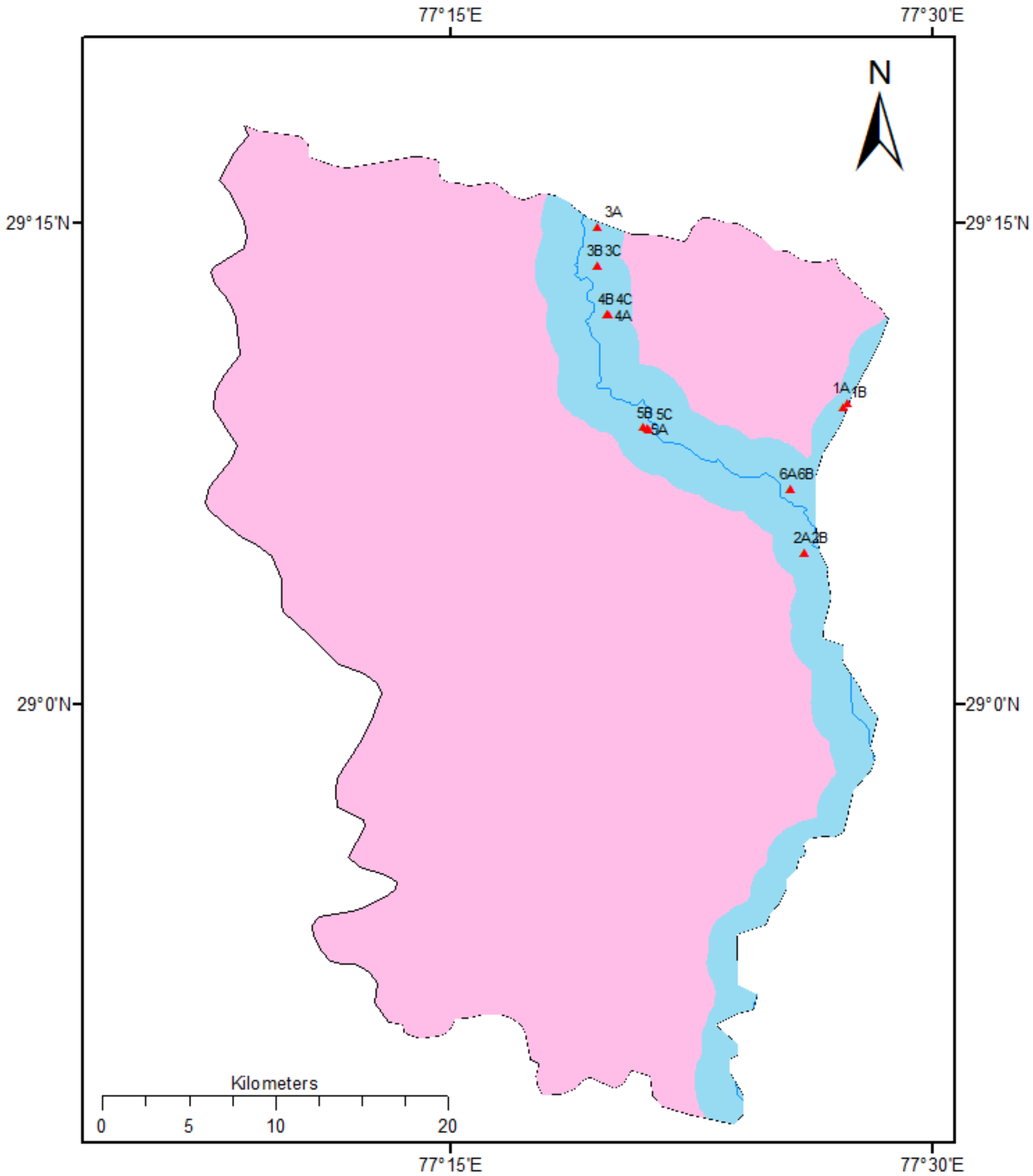


Fig. 4.10 Ground Water Sampling Locations in District Baghpat in Two km Buffer Zone of River Hindon and Krishni

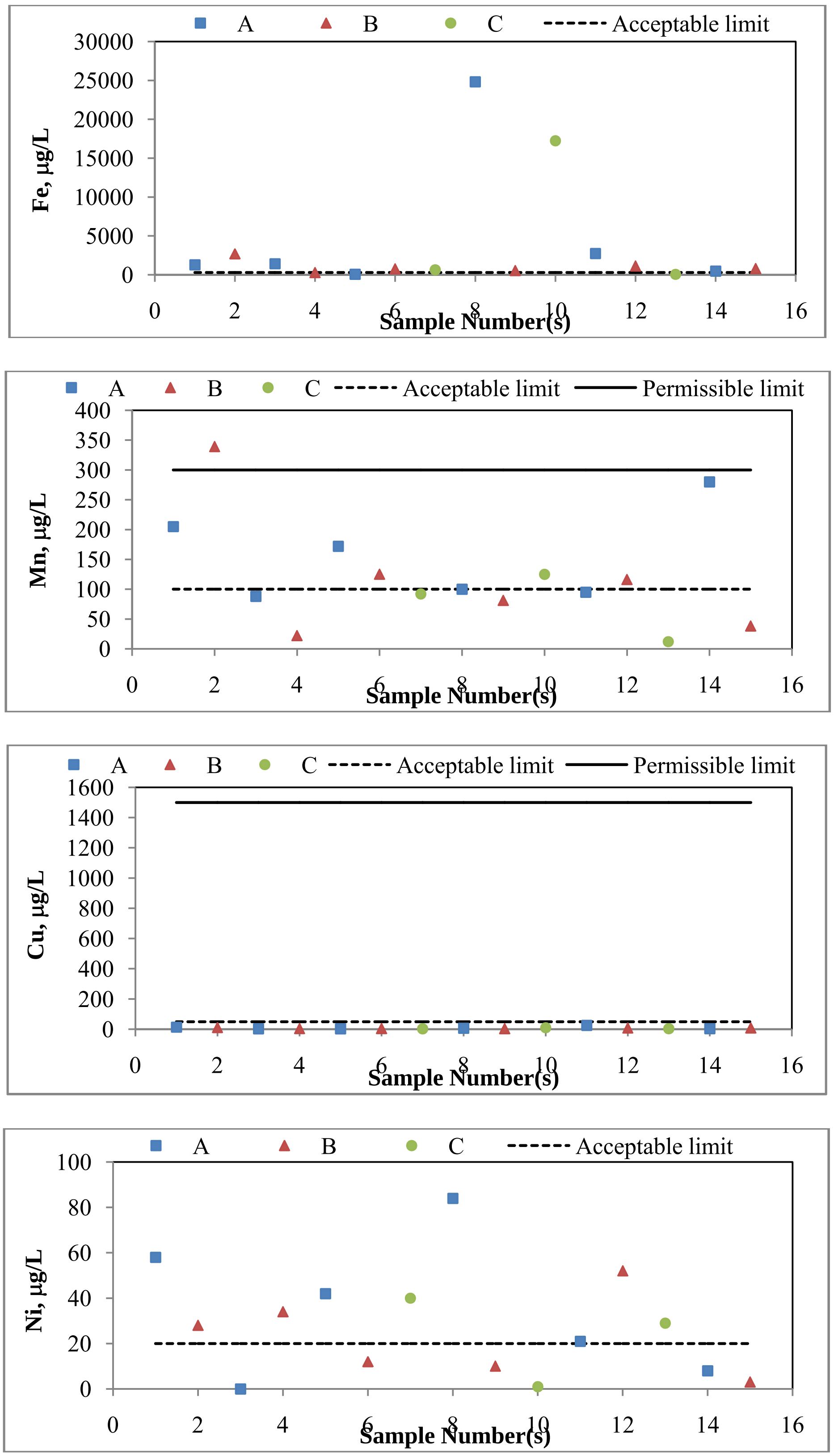
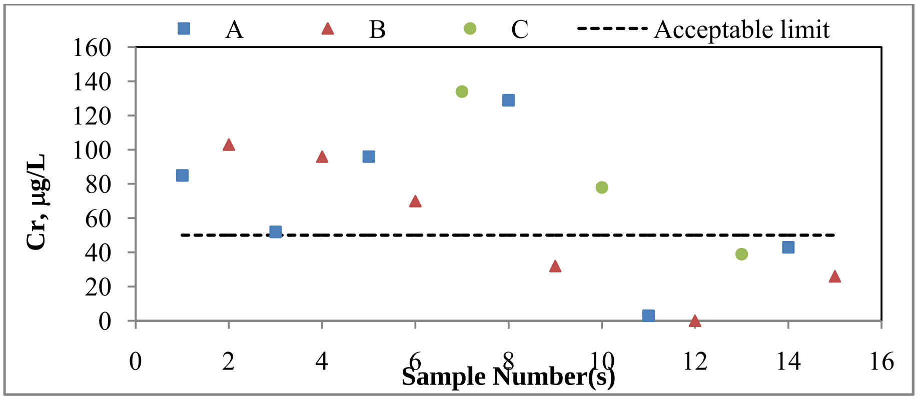
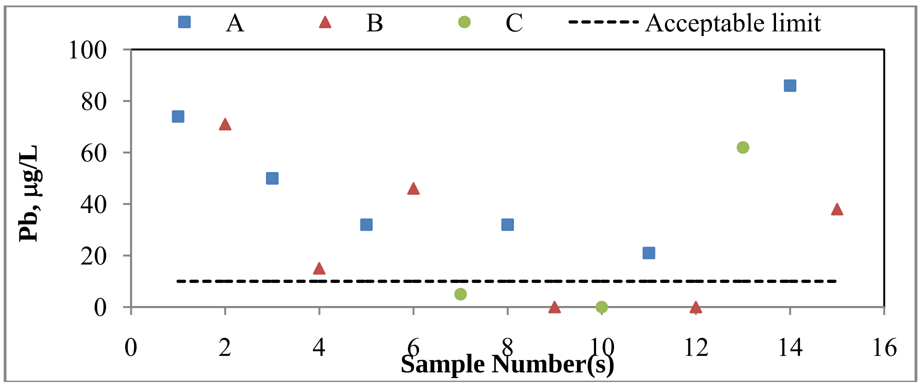
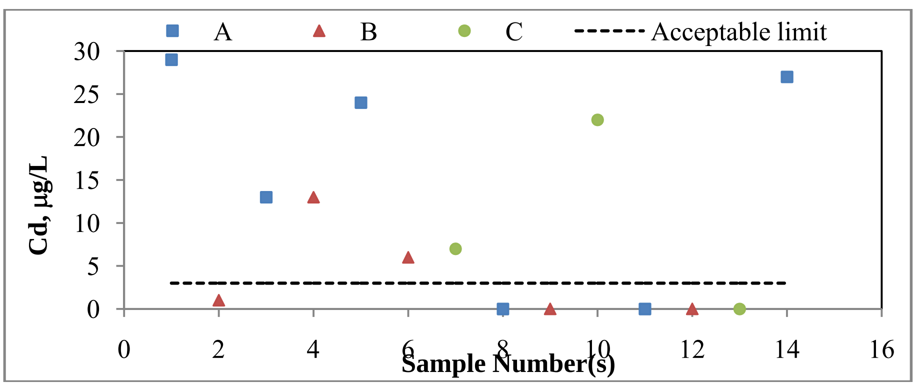


Fig. 4.11 Distribution of Trace Elements in Ground Water of District Baghpat







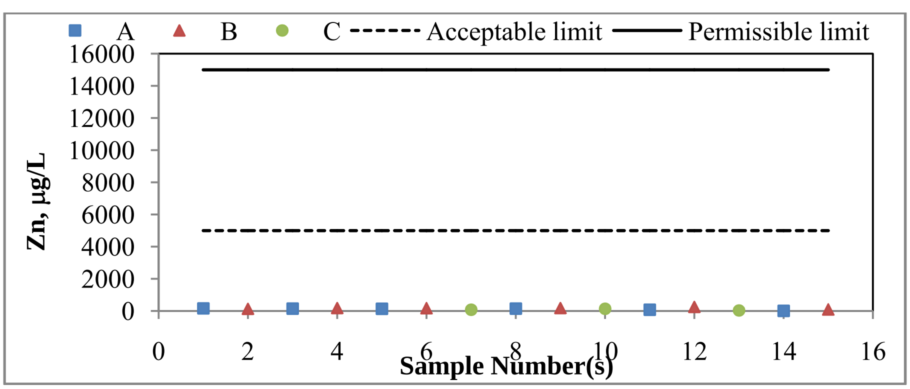


Fig. 4.11 (Contd.) Distribution of Trace Elements in Ground Water of District Baghpat

Table 4.17 Hydro-chemical Data of Ground Water Samples of District Baghpat (March 2013)

S.No.	Sample ID	Location	Source	Depth	pH	EC	TDS	Alk	Hard	Na	K	Ca	Mg	HCO3	Cl	SO4	NO3	PO4	F	BOD	COD
				m		μS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1	BPM-1A	Khaprana	HP	14	7.1	1440	922	452	362	122	6.1	76	42	551	36	7.5	74	0.12	1.53	1.6	3.5
2	BPM-1B	Khaprana	IM II	37	7.8	1371	877	248	206	168	5.9	48	21	303	72	35	220	0.06	0.49	1.2	3.2
3	BPM-2A	Galheta	HP	34	7.5	1118	716	252	188	145	4.4	39	22	307	60	50	82	0.08	1.15	1.4	3.4
4	BPM-2B	Galheta	IM II	37	7.8	758	485	202	124	98	4.0	30	12	246	48	30	13	0.06	0.27	1.6	4.2
5	BPM-3A	Himmatpur	HP	52	7.2	1485	950	472	283	170	6.5	59	33	576	50	43	8.6	0.08	0.5	0.8	1.8
6	BPM-3B	Himmatpur	IM II	61	7.7	998	639	332	201	102	4.9	36	27	405	24	33	4.6	0.04	0.02	1.0	3.4
7	BPM-3C	Himmatpur	TW	79	7.2	1010	646	326	199	110	4.3	37	26	398	18	45	5.3	0.04	0.52	0.8	2.8
8	BPM-4A	Gangnoli	HP	43	9.0	665	426	206	74	96	8.0	13	10	251	30	9.5	5.3	0.08	ND	1.4	3.2
9	BPM-4B	Gangnoli	IM II	61	7.4	895	573	316	158	102	5.2	32	19	386	20	5.0	0.6	0.04	0.27	0.6	1.4
10	BPM-4C	Gangnoli	TW	55	7.6	915	586	328	159	104	4.8	26	23	400	14	7.0	1.8	0.04	0.71	0.4	1.0
11	BPM-5A	Bamnauli	HP	37	7.5	965	618	332	166	112	5.0	27	24	405	32	5.0	2.6	0.09	0.26	1.2	3.2
12	BPM-5B	Bamnauli	IM II	43	7.6	1017	651	303	183	116	4.3	32	25	370	84	13	4.3	0.04	0.72	1.4	4.6
13	BPM-5C	Bamnauli	BW(PS)	122	7.7	932	596	308	166	110	6.8	27	24	376	32	12	6.5	0.02	0.65	0.4	1.4
14	BPM-6A	Barnawa	HP	30	7.1	1296	829	366	348	105	7.3	62	47	447	52	13	94	0.16	ND	1.4	3.8
15	BPM-6B	Barnawa	IM II	37	7.3	1185	758	312	313	95	5.6	66	36	381	120	5.5	45	0.08	0.5	1.2	3.4
		Minimum			7.1	665	426	202	74	95	4.0	13	10	246	14	5.0	0.6	0.02	ND	0.4	1.0
		Maximum			9.0	1485	950	472	362	170	8.0	76	47	576	120	50	220	0.16	1.53	1.6	4.6
		Mean			7.6	1070	685	317	209	117	5.5	41	26	387	46	21	38	0.07	0.58	1.1	3.0

Table 4.18 Bacteriological Data of Ground Water Samples of District Baghpat (March 2013)						
S.No.	Sample ID	Location	Source	Depth	Total Coliform	Fecal Coliform
				m	per 100 ml	per 100 ml
1	BPM-1A	Khaprana	HP	14	<3	<3
2	BPM-1B	Khaprana	IM II	37	<3	<3
3	BPM-2A	Galheta	HP	34	43	<3
4	BPM-2B	Galheta	IM II	37	<3	<3
5	BPM-3A	Himmatpur	HP	52	<3	<3
6	BPM-3B	Himmatpur	IM II	61	<3	<3
7	BPM-3C	Himmatpur	TW	79	<3	<3
8	BPM-4A	Gangnoli	HP	43	<3	<3
9	BPM-4B	Gangnoli	IM II	61	<3	<3
10	BPM-4C	Gangnoli	TW	55	<3	<3
11	BPM-5A	Bamnauli	HP	37	<3	<3
12	BPM-5B	Bamnauli	IM II	43	<3	<3
13	BPM-5C	Bamnauli	BW(PS)	122	4	<3
14	BPM-6A	Barnawa	HP	30	150	4
15	BPM-6B	Barnawa	IM II	37	<3	<3

Table 4.19 Trace Element Data of Ground Water Samples of District Baghpat (March 2013)

S.No.	Sample ID	Location	Source	Depth	Fe	Mn	Cu	Ni	Cr	Pb	Cd	Zn	As
				m	μg/L	μg/L	μg/L	μg/L	μg/L	μg/L	μg/L	μg/L	μg/L
1	BPM-1A	Khaprana	HP	14	1288	205	14	58	85	74	29	165	ND
2	BPM-1B	Khaprana	IM II	37	2691	339	11	28	103	71	1.0	136	ND
3	BPM-2A	Galheta	HP	34	1423	88	3.0	ND	52	50	13	152	ND
4	BPM-2B	Galheta	IM II	37	273	22	4.0	34	96	15	13	188	ND
5	BPM-3A	Himmatpur	HP	52	62	172	3.0	42	96	32	24	145	ND
6	BPM-3B	Himmatpur	IM II	61	752	125	4.0	12	70	46	6.0	172	ND
7	BPM-3C	Himmatpur	TW	79	633	92	3.0	40	134	5.0	7.0	84	ND
8	BPM-4A	Gangnoli	HP	43	24828	100	7.0	84	129	32	ND	152	ND
9	BPM-4B	Gangnoli	IM II	61	528	81	3.0	10	32	ND	ND	188	ND
10	BPM-4C	Gangnoli	TW	55	17235	125	10	1.0	78	ND	22	145	ND
11	BPM-5A	Bamnauli	HP	37	2737	95	26	21	3.0	21	ND	85	ND
12	BPM-5B	Bamnauli	IM II	43	1114	116	8.0	52	ND	ND	ND	256	ND
13	BPM-5C	Bamnauli	BW(PS)	122	59	12	4.0	29	39	62	ND	36	ND
14	BPM-6A	Barnawa	HP	30	474	280	4.0	8.0	43	86	27	14	ND
15	BPM-6B	Barnawa	IM II	37	784	38	8.0	3.0	26	38	2.0	90	ND
		Minimum			59	12	3.0	ND	3.0	5.0	1.0	14	ND
		Maximum			24828	339	26	84	134	86	29	256	ND
		Mean			3659	126	7.5	30	70	44	14	134	ND

4.2.6 District Ghaziabad

Total 5 ground water samples from private hand pumps, IM II hand pumps and bore well were collected from 2 villages in the buffer zone of 2 km on the banks of River Hindon falling in District Ghaziabad (Fig. 4.12) and the results (Tables 4.20 to 4.22) have been discussed in the following sections.

General Characteristics

The pH values in the ground water samples collected from District Ghaziabad fall within the range of 7.0 to 8.2 in private hand pumps, IM II hand pumps and bore well. The pH values for all of the samples are well within the limits prescribed by BIS (2012) for various uses of water including drinking and other domestic supplies.

The electrical conductivity and dissolved salt concentrations are directly related to the concentration of ionized substance in water and may also be related to problems of excessive hardness and/or other mineral contamination. The conductivity values in the ground water samples vary from 892 to 2092 μS/cm in private hand pumps, IM II hand pumps and bore well. The conductivity above 1000 μS/cm was observed in private hand pumps of Surana and Bhanera with maximum conductivity value of 2092 μS/cm in the private hand pump of village Surana.

The TDS value in the ground water samples collected from District Ghaziabad varies from 571 to 1339 mg/L in private hand pumps, IM II hand pumps and bore well. TDS values above the acceptable limit of 500 mg/L were observed in all ground water samples collected from District Ghaziabad. Water containing more than 500 mg/L of TDS is not considered acceptable for drinking water supplies, though more highly mineralized water is also used where better water is not available. For this reason, 500 mg/L as the acceptable limit and 2000 mg/L as the maximum permissible limit has been suggested for drinking water (BIS, 2012). None of the collected samples from District Ghaziabad exceeded the permissible limit of 2000 mg/L. Water containing TDS more than 500 mg/L causes gastrointestinal irritation.

Alkalinity in natural water is mainly due to presence of carbonates, bicarbonates and hydroxides. Bicarbonates represent the major form since they are formed in considerable amount from the action of carbonates upon the basic materials in the soil. The alkalinity value in the collected samples from District Ghaziabad varies from 306 to 376 mg/L in private hand pumps, IM II hand pumps and bore well. All of the samples collected from private hand pumps, IM II hand pumps and bore well exceeded the acceptable limit of 200 mg/L but within the maximum permissible limit of 600 mg/L.

Hardness of water is due to carbonates, sulphates and chlorides of calcium and magnesium. A limit of 200 mg/L as acceptable limit and 600 mg/L as permissible limit has been recommended for drinking water (BIS, 2012). The total hardness values in the samples collected from District Ghaziabad range from 253 to 352 mg/L in private hand pumps, IM II hand pumps and bore well. None of the ground water sample collected from District Ghaziabad crossed the permissible limit of 600 mg/L.

In ground water of the samples collected from District Ghaziabad, the values of calcium range from 42 to 71 mg/L and magnesium range from 23 to 43 mg/L in private hand pumps, IM II hand pumps and bore well. The acceptable limit for calcium and magnesium for drinking water are 75 and 30 mg/L respectively (BIS, 2012). In ground water, the calcium content generally exceeds the magnesium content in accordance with their relative abundance in rocks. All ground water samples collected from District Ghaziabad fall within the maximum permissible limit of 200 mg/L of calcium and 100 mg/L of magnesium.

The concentration of sodium in the the samples collected from District Ghaziabad varies from 49 to 108 mg/L in private hand pumps, IM II hand pumps and bore well. The Bureau of Indian Standards has not included sodium in drinking water standards. The high sodium values in the collected samples may be attributed to base-exchange phenomena and causes sodium hazard. Ground water with such high sodium is not suitable for irrigation purpose.

Potassium is an essential element for humans, plants and animals and derived in food chain mainly from vegetation and soil. The main sources of potassium in ground water include rain water, weathering of potash silicate minerals, use of potash fertilizers and use of surface water for irrigation. The concentration of potassium in the ground water samples collected from District Ghaziabad varies from 6.4 to 249 mg/L in private hand pumps, IM II hand pumps and bore well. The Bureau of Indian Standards has not included potassium in drinking water standards. However, the European Economic Community has prescribed guideline level of potassium at 10 mg/L in drinking water. As per EEC criteria, the ground water samples collected from private hand pump and IM II hand pump of village Surana exceed the guideline level of 10 mg/L.

The concentration of chloride in the samples collected from District Ghaziabad varies from 8.0 to 172 mg/L in private hand pumps, IM II hand pumps and bore well. All samples were observed within the acceptable limit of 250 mg/L. The limits of chloride have been laid down primarily from taste considerations. A limit of 250 mg/L chloride has been recommended as acceptable limit and 1000 mg/L as the permissible limit for drinking water (BIS, 2012). However, no adverse health effects on humans have been reported from intake of waters containing even higher content of chloride.

The concentration of sulphate in the samples collected from District Ghaziabad varies from 24 to 108 mg/L in private hand pumps, IM II hand pumps and bore well. Bureau of Indian standard has prescribed 200 mg/L as the acceptable limit and 400 mg/L as the permissible limit for sulphate in drinking water. In the samples collected from District Ghaziabad, none of the samples exceeded the maximum acceptable limit of 200 mg/L.

Nitrate content in drinking water is considered important for its adverse health effects and moderately toxicity. A limit of 45 mg/L has been prescribed by BIS (2012) for drinking water supplies. Its concentration above 45 mg/L may prove detriment to human health. In higher concentrations, nitrate may produce a disease known as methaemoglobinaemia (blue babies) which generally affects bottle-fed infants. Repeated heavy doses of nitrates on ingestion may also cause carcinogenic diseases. The nitrate content in the samples collected from District Ghaziabad varies from 1.6 to 157 mg/L in private hand pumps, IM II hand pumps and bore well.

The nitrate concentration was observed more than permissible limit of 45 mg/L in ground water samples from private hand pump of village Surana, which may be attributed to contamination by industrial/domestic waste disposal.

The presence of fluoride in ground water may be attributed to the localized effects of natural sources. The fluoride is present in soil strata due to the presence of geological formations like fluorspar, fluorapatite, ampheboles such as hornblinde, trimolite and mica. Weathering of alkali, silicate, igneous and sedimentary rocks specially shales contribute a major portion of fluorides to ground waters. In addition to natural sources, considerable amount of fluorides may be contributed due to man's activities. Fluoride salts are commonly used in steel, aluminium, bricks and tile-industries. The fluoride containing insecticides and herbicides may be contributed through agricultural runoff. Phosphatic fertilizers, which are extensively used, often contain fluorides as impurity and these may increase levels of fluoride in soil. The accumulation of fluoride in soil eventually results in its leaching due to percolating water, thus increase fluoride concentration in ground water. The fluoride content in the ground water samples collected from District Ghaziabad varies from 0.57 to 1.52 mg/L in private hand pumps, IM II hand pumps and bore well. Ground water sample collected from private hand pump of village Surana exceeds the maximum permissible limit of 1.5 mg/L.

From the above discussion, it is clearly evident that in the ground water samples collected from District Ghaziabad, the concentration of total dissolved solids was observed above the acceptable limit of 500 mg/L in all the ground water samples collected from district Ghaziabad but none of the samples exceeded the maximum permissible limit of 2000 mg/L. None of the samples exceeded the maximum permissible limit of hardness of 600 mg/L. The concentration of nitrate exceeded the permissible limit in ground water samples collected from the private hand pumps of village Surana. The concentration of fluoride was observed to exceed the maximum permissible limit in ground water of village Surana. The violation of BIS limit could not be ascertained for sodium and potassium as no permissible limit for these constituents has been prescribed in BIS drinking water specifications. On the basis of above results, it can be inferred that ground water from private hand pumps have the problem of TDS, nitrate and fluoride specially in the area of Surana, which may be attributed to possible impact of effluents discharged into river Hindon on the ground water.

Bacteriological Parameters

In water quality control technology, the principal indicator of suitability of water for domestic, industrial or other uses is the coliform group of bacteria. The density of coliform group is the criteria for the extent of contamination and has been the basis for bacteriological water quality standard. Further, the presence of faecal colifirms in water is the indicator of a potential public health problem, because faecal matter is a source of pathogenic bacteria and viruses. The faecal coliform bacteria contaminate water through percolation from contamination sources (domestic sewage and septic tank) and also because of poor sanitary system. The indiscriminate land disposal of domestic waste on surface and improper disposal of solid waste further aggravate the problem of bacterial contamination in water. The collected samples from District Ghaziabad were analysed for bacteriological parameters viz; Total Coliform and Faecal

Coliform. The result of bacteriological analysis is given in Table 4.21. The result shows that the bacterial contamination was observed in ground water of village Bhanera of District Ghaziabad.

Heavy Metals

Heavy metals in ground water have a considerable significance due to their toxicity and adsorption behaviour. Heavy metals are not biodegradable and enter the food chain through a number of pathways causing progressive toxicity due to the accumulation in human and animal organs during their life span on long term exposure to contaminated environments. Despite the presence of trace concentrations of Cr, Mn, Co, Cu and Zn in the aquatic environment, which is essential to a number of life processes, high concentrations of these metals become toxic. The major sources of heavy metals in ground water include weathering of rock minerals, discharge of sewage and other waste effluents on land and runoff water. The trace element data of ground water samples collected from the District Ghaziabad is given in Table 4.22. The distribution of different metals is shown graphically in Fig. 4.13. The toxic effects of these elements and extent of their contamination in ground water is discussed in the following sections.

Iron (Fe): The concentration of iron in the ground water samples collected from District Ghaziabad ranges from 0.030 to 5.502 mg/ in private hand pumps, IM II hand pumps and bore well. The Bureau of Indian Standards has recommended 0.3 mg/L as the acceptable limit for iron in drinking water (BIS, 2012). WHO has prescribed 0.3 mg/L as the acceptability threshold value for iron (WHO, 2011). It is evident from the results that about 80% samples collected from the district exceed the acceptable limit of 0.3 mg/L. Highest concentration of iron 5.502 mg/L was observed in the ground water collected from IM II hand pump of Surana. The higher concentration of iron in the almost all ground water samples may be attributed to leaching of industrial wastes flowing into the River Hindon.

It is a known fact that iron in trace amounts is essential for nutrition. High concentrations of iron generally cause inky flavour, bitter and astringent taste to water. Well water containing soluble iron remain clear while pumped out, but exposure to air causes precipitation of iron due to oxidation, with a consequence of rusty colour and turbidity. The objection to iron in the distribution system is not due to health reason but to staining of laundry and plumbing fixtures and appearance. Taste and order problems may be caused by filamentous organism that prey on iron compounds (frenothrix, gallionella and leptothrix are called iron bacteria), originating another consumer’s objection (red water). The presence of iron bacteria may clog well screens or develop in the distribution system, particularly when sulphate compounds in addition to iron may be subjected to chemical reduction.

Manganese (Mn): The concentration of manganese in the ground water samples collected from District Ghaziabad ranges from 0.026 to 0.150 mg/L in private hand pumps, IM II hand pumps and bore well. Manganese is an essential trace nutrient for plants and animals, which does not occur naturally as a metal but is found in various salts and minerals frequently in association with iron compounds. Manganese may gain entry into the body by inhalation, consumption of food and through drinking water. A concentration of 0.1 mg/L has been recommended as an acceptable limit and 0.3 mg/L as the permissible limit for drinking water (BIS, 2012). WHO has prescribed 0.1 mg/L as the acceptability threshold value and 0.4 mg/L as health based value (WHO, 2011). It is evident from the results that about 40% of the samples collected from private hand pumps, IM II hand pumps and bore well fall within the acceptable limit of 0.1 mg/L and none of the samples exceeds the maximum permissible limit of 0.3 mg/L. The presence of manganese above permissible limit of drinking water often imparts alien taste to water. It also has adverse effects on domestic uses and water supply structures.

Copper (Cu): The concentration of copper in the ground water samples collected from District Ghaziabad ranges from 0.004 to 0.036 mg/L in private hand pumps, IM II hand pumps and bore well. The Bureau of Indian Standards has recommended 0.05 mg/L as the acceptable limit and 1.5 mg/L as the permissible limit in the absence of alternate source (BIS, 2012). Beyond 0.05 mg/L the water imparts astringent taste and cause discoloration and corrosion of pipes, fittings and utensils. World Health Organization has recommended 2.0 mg/L as the provisional guideline value for drinking purpose (WHO, 2011). In the present investigation, none of the samples collected from the District Ghaziabad exceeds the acceptable limit of 0.05 mg/L.

Nickel (Ni): The concentration of nickel in the ground water samples collected from District Ghaziabad ranges from ND to 0.079 mg/L in private hand pumps, IM II hand pumps and bore well. The Bureau of Indian Standards has recommended 0.02 mg/L as the acceptable limit (BIS, 2012). World Health Organization has recommended 0.07 mg/L as the guideline value for drinking purposes (WHO, 2011). In this range it is not harmful in drinking water. Ground water samples collected from private hand pumps of Surana and Bhanera exceed the BIS limit of 0.02 mg/L.

Chromium (Cr): The concentration of chromium in the ground water samples collected from District Ghaziabad ranges from 0.007 to 0.080 mg/L in private hand pumps, IM II hand pumps and bore well. A concentration of 0.05 mg/L has been recommended as an acceptable limit for drinking water (BIS, 2012). WHO has also prescribed 0.05 mg/L as the guideline value for drinking water (WHO, 2011). One ground water sample collected from private hand pump of Surana exceeds the BIS limit of 0.05 mg/L.

Hexavalent chromium has a deleterious effect on the liver, kidney, and respiratory organs with hemorrhagic effects, dermatitis, and ulceration of the skin for chronic and subchronic exposure. Municipal wastewater release considerable amount of chromium into the environment. In the natural environment, Cr(+6) is likely to be reduced to Cr(+3), thereby reducing the toxic impact of chromium discharges. The pathways of chromium contribution to ground water are that the chromium containing industrial effluent discharged into stream, the hexavalent state chromium may be reduced to trivalent state and later adsorbed on the suspended particulate. In case, it could not be adsorbed, the chromium remain in the form of colloidal suspension, may precipitate and become part of stream sediment, from where it may reach to ground water through percolation containing shallow aquifers.

Lead (Pb): In the ground water samples collected from District Ghaziabad, the concentration of lead ranges from ND to 0.086 mg/L in private hand pumps, IM II hand pumps and bore well. The Bureau of Indian Standards has prescribed 0.01 mg/L lead as the desirable limit for drinking water (BIS, 2012). Beyond this limit, the water becomes toxic. WHO has also prescribed 0.01 mg/L as guideline value for drinking water (WHO, 2011). Ground water samples collected from private hand pump and IM II hand pump of Surana exceed the BIS limit of 0.01 mg/L.

Lead is not considered an essential nutritional element and is a cumulative poison to humans. Acute lead poisoning is extremely rare. The typical symptoms of advanced lead poisoning are constipation, anemia, gastrointestinal disturbance, tenderness and gradual paralysis in muscles, specifically arms with possible cases of lethargy and moroseness. The major source of lead contamination is the combustion of fossil fuel. Lead is removed from the atmosphere by rain and falls back on the earth surface and seeps into the ground. Lead passes from the soil to water and to the plants and finally into the food chain. In drinking water it occurs primarily due to corrosion of lead pipes and solders, especially in areas of soft water. It may be noted that the use of soft water of slightly acidic pH and the use of lead pipes in service and domestic water lines may provide higher concentrations of lead at the consumers's tap, particularly when the water use is minimal in the household (overnight still water in pipes).

Cadmium (Cd): In the ground water samples collected from District Ghaziabad, the concentration of cadmium ranges from 0.005 to 0.015 mg/L in private hand pumps, IM II hand pumps and bore well. The Bureau of Indian Standards has prescribed 0.003 mg/L cadmium as the acceptable limit for drinking water (BIS, 2012). Beyond this limit, the water becomes toxic. WHO has also prescribed 0.003 mg/L cadmium as the guideline value for drinking water (WHO, 2011). The drinking water having more than 3 μg/L of cadmium can cause bronchitis, emphysema, anaemia and renal stone formation in animals. All the ground water samples collected from district exceed the BIS limit of 0.003 mg/L.

Zinc (Zn): The concentration of zinc in the ground water samples collected from District Ghaziabad ranges from 0.018 to 0.364 mg/L in private hand pumps, IM II hand pumps and bore well. The Bureau of Indian Standards has prescribed 5.0 mg/L zinc as the acceptable limit and 15 mg/L as the permissible limit for drinking water (BIS, 2012). WHO has prescribed 3.0 mg/L as the guideline value for drinking water (WHO, 2011). All the samples were found within the desirable limit prescribed by BIS (2012) and WHO (2011).

Arsenic (As): In the ground water samples collected from District Ghaziabad, the concentration of arsenic was not detected. Ground water is expected to contain higher arsenic concentrations than surface water. Because of its presence in geological materials, arsenic can be traced in water as originated by natural processes or by industrial activities – industrial waste, arsenical pesticides and smelting operations. Generally, arsenic found in two state – As(III) and As(V) in ground water. As(III) compounds are more toxic than As(V) compounds. Arsenic compounds are skin and lung carcinogens in humans. The Bureau of Indian Standards has prescribed 0.01 mg/L arsenic as the acceptable limit and 0.05 mg/L as the permissible limit for drinking water (BIS, 2012). Beyond this limit, the water becomes toxic. WHO has prescribed 0.01 mg/L arsenic as the guideline value for drinking water (WHO, 2011). In the present investigation, all the ground water samples collected from District Ghaziabad were found within the acceptable limit prescribed by BIS (2012).

From the above results, it is quite clear that the presence of heavy metals has been recorded in many location and the water quality standards have been violated for iron (4 samples), nickel (2 samples), chromium (1 sample), lead (2 samples) and cadmium (5 samples) out of collected 5 samples from private hand pumps, IM II hand pumps and bore well of District Ghaziabad.

Pesticides

The analysis of nine organo-chlorinated pesticides (Aldrin, α-BHC, β-BHC, γ-BHC, δ-BHC, DDD, DDE, Endosulphan and Methoxychlor) was carried out in ground water samples from IM II hand pump of Surana and Bhanera of District Ghaziabad but none of the pesticide has been detected in the analysed samples.

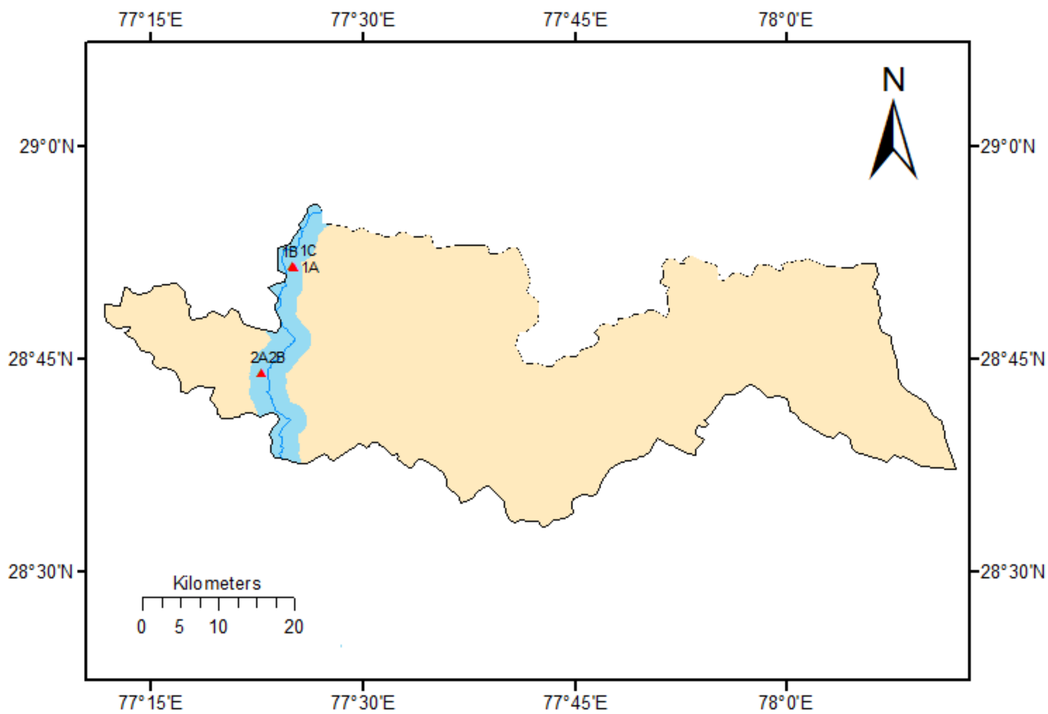


Fig. 4.12 Ground Water Sampling Locations in District Ghaziabad in Two km Buffer Zone of River Hindon

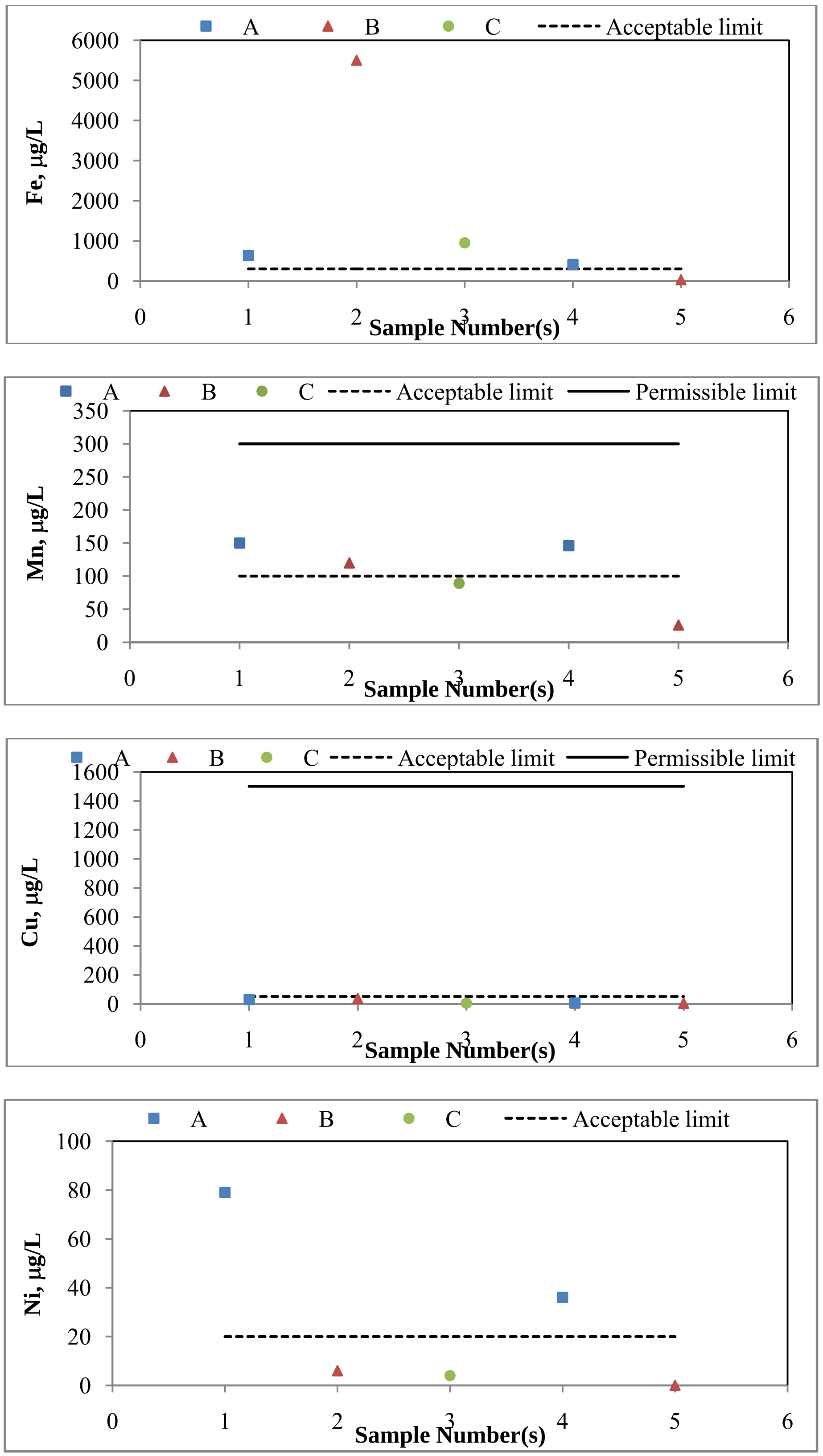
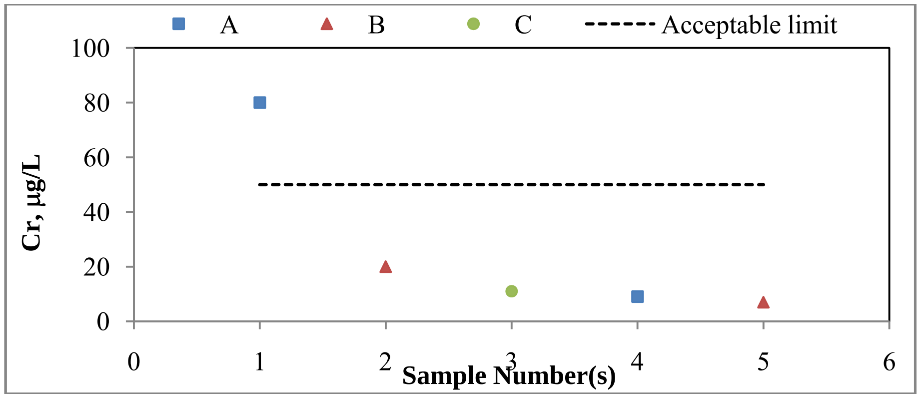
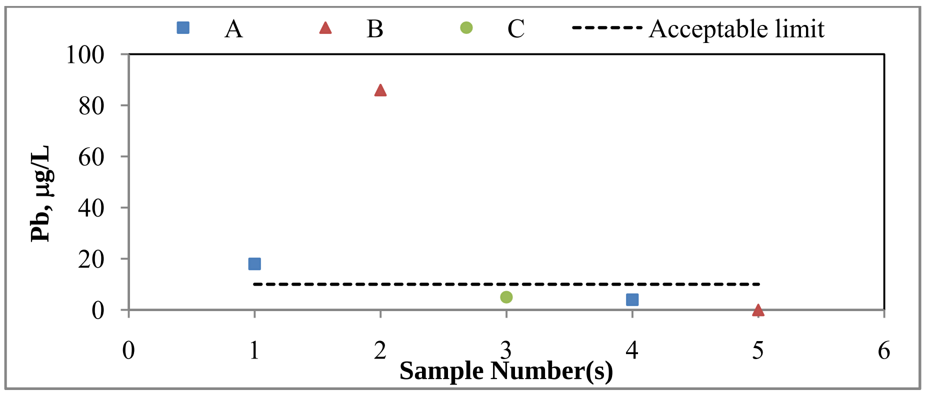
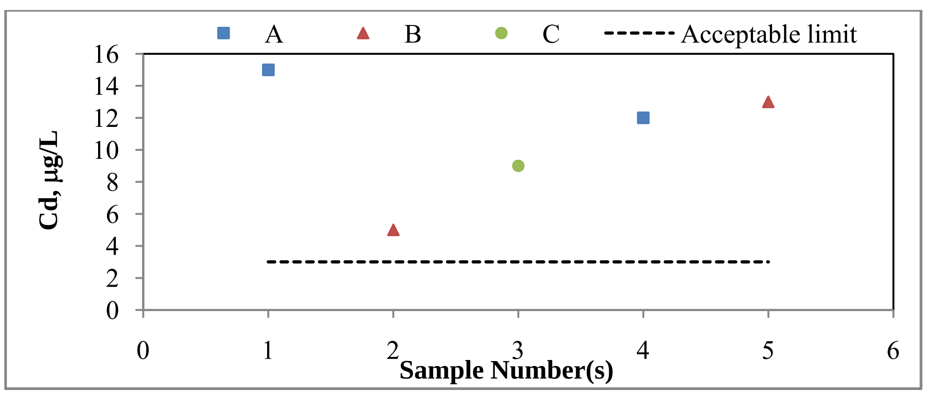


Fig. 4.13 Distribution of Trace Elements in Ground Water of District Ghaziabad







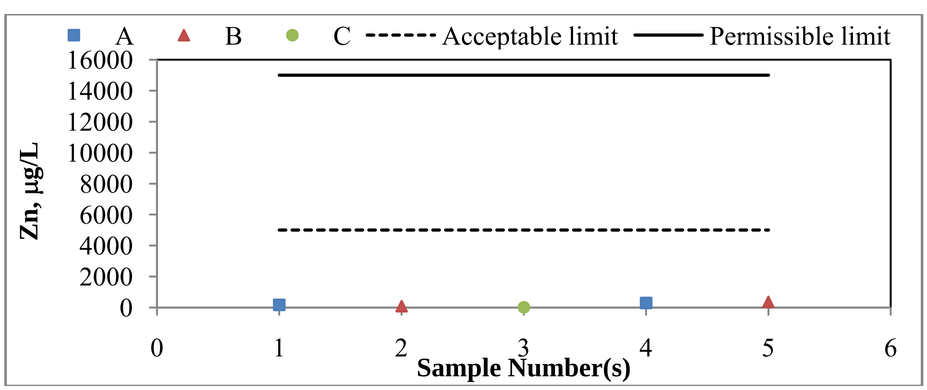


Fig. 4.13 (Contd.) Distribution of Trace Elements in Ground Water of District Ghaziabad

Table 4.20 Hydro-chemical Data of Ground Water Samples of District Ghaziabad (March 2013)

S.No.	Sample ID	Location	Source	Depth	pH	EC	TDS	Alk	Hard	Na	K	Ca	Mg	HCO3	Cl	SO4	NO3	PO4	F	BOD	COD
				m		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1	GZB-1A	Surana	HP	24	7.2	2092	1339	352	352	108	249	70	43	429	172	108	157	0.12	1.52	0.8	3.1
2	GZB-1B	Surana	IM II	43	7.3	935	598	306	294	49	18	52	40	373	36	24	1.6	0.06	0.64	0.6	2.2
3	GZB-1C	Surana	BW(PS)	76	7.0	994	636	310	272	71	6.6	71	23	378	30	40	12	0.02	0.66	0.4	1.8
4	GZB-2A	Bhanera	HP	21	7.1	1098	703	376	270	92	6.7	54	33	459	26	25	4.2	0.14	0.57	1.0	3.4
5	GZB-2B	Bhanera	IM II	37	8.2	892	571	312	253	62	6.4	42	36	381	8.0	30	5.4	0.08	0.64	0.6	2.2
		Minimum			7.0	892	571	306	253	49	6.4	42	23	373	8.0	24	1.6	0.02	0.57	0.4	1.8
		Maximum			8.2	2092	1339	376	352	108	249	71	43	459	172	108	157	0.14	1.52	1.0	3.4
		Mean			7.4	1202	769	331	288	76	57	58	35	404	54	45	36	0.08	0.81	0.7	2.5

Table 4.21 Bacteriological Data of Ground Water Samples of District Ghaziabad (March 2013)

S.No.	Sample ID	Location	Source	Depth	Total Coliform	Fecal Coliform
				m	per 100 ml	per 100 ml
1	GZB-1A	Surana	HP	24	<3	<3
2	GZB-1B	Surana	IM II	43	<3	<3
3	GZB-1C	Surana	BW(PS)	76	<3	<3
4	GZB-2A	Bhanera	HP	21	4	<3
5	GZB-2B	Bhanera	IM II	37	<3	<3

Table 4.22 Trace Element Data of Ground Water Samples of District Ghaziabad (March 2013)

S.No.	Sample ID	Location	Source	Depth	Fe	Mn	Cu	Ni	Cr	Pb	Cd	Zn	As
				m	μg/L	μg/L	μg/L	μg/L	μg/L	μg/L	μg/L	μg/L	μg/L
1	GZB-1A	Surana	HP	24	634	150	29	79	80	18	15	167	ND
2	GZB-1B	Surana	IM II	43	5502	120	36	6.0	20	86	5.0	90	ND
3	GZB-1C	Surana	BW(PS)	76	952	89	4.0	4.0	11	5.0	9.0	18	ND
4	GZB-2A	Bhanera	HP	21	411	146	5.0	36	9.0	4.0	12	294	ND
5	GZB-2B	Bhanera	IM II	37	30	26	4.0	ND	7.0	ND	13	364	ND
		Minimum			30	26	4.0	ND	7.0	ND	5.0	18	ND
		Maximum			5502	150	36	79	80	86	15	364	ND
		Mean			1506	106	16	31	25	28	11	187	ND

4.2.7 District Gautambudh Nagar

Total 9 ground water samples from private hand pumps, IM II hand pumps and bore wells/tube well were collected from 3 villages viz; Bisrakh Jalalpur, Surajpur and Momna Thal in the buffer zone of 2 km on the banks of River Hindon falling in District Gautambudh Nagar (Fig. 4.14) and the results (Table 4.23 to 4.25) have been discussed in the following sections.

General Characteristics

The pH values in the ground water samples collected from District Gautambudh Nagar fall within the range of 7.2 to 8.0 in private hand pumps, IM II hand pumps and bore wells/tube well. The pH values for all of the samples are well within the limits prescribed by BIS (2012) for various uses of water including drinking and other domestic supplies.

The electrical conductivity and dissolved salt concentrations are directly related to the concentration of ionized substance in water and may also be related to problems of excessive hardness and/or other mineral contamination. The conductivity values in the ground water samples vary from 446 to 1552 μS/cm in private hand pumps, IM II hand pumps and bore wells/tube well. The conductivity above 1000 μS/cm was observed in private hand pump of Surajpur and IM II hand pumps and bore wells of Bisrakh Jalalpur and Surajpur. Maximum conductivity value of 1552 μS/cm was observed in the private hand pump of village Surajpur.

The TDS value in the ground water samples collected from District Gautambudh Nagar varies from 285 to 993 mg/L in private hand pumps, IM II hand pumps and bore wells/tube well. TDS values above the acceptable limit of 500 mg/L were observed in ground water samples collected from private hand pump of Surajpur, IM II hand pump of Bisrakh Jalalpur, Surajpur and bore wells/tube well of Bisrakh Jalalpur, Surajpur and Momna Thal of District Gautambudh Nagar. Water containing more than 500 mg/L of TDS is not considered acceptable for drinking water supplies, though more highly mineralized water is also used where better water is not available. For this reason, 500 mg/L as the acceptable limit and 2000 mg/L as the permissible limit has been suggested for drinking water (BIS, 2012). None of the collected samples from District Gautambudh Nagar exceeded the permissible limit of 2000 mg/L. Water containing TDS more than 500 mg/L causes gastrointestinal irritation.

Alkalinity in natural water is mainly due to presence of carbonates, bicarbonates and hydroxides. Bicarbonates represent the major form since they are formed in considerable amount from the action of carbonates upon the basic materials in the soil. The alkalinity value in the collected samples from District Gautambudh Nagar varies from 136 to 456 mg/L in private hand pumps, IM II hand pumps and bore wells/tube well. Seven samples collected from private hand pumps, IM II hand pumps and bore wells/tube well exceeded the acceptable limit of 200 mg/L but are within the maximum permissible limit of 600 mg/L.

Hardness of water is due to carbonates, sulphates and chlorides of calcium and magnesium. A limit of 200 mg/L as acceptable limit and 600 mg/L as permissible limit has been recommended for drinking water (BIS, 2012). The total hardness values in the samples collected from District Gautambudh Nagar range from 64 to 381 mg/L in private hand pumps, IM II hand pumps and bore wells/tube well. None of the ground water sample collected from District Gautambudh Nagar crossed the permissible limit of 600 mg/L.

In ground water of the samples collected from District Gautambudh Nagar, the values of calcium range from 14 to 82 mg/L and magnesium range from 7.0 to 43 mg/L in private hand pumps, IM II hand pumps and bore wells/tube well. The acceptable limit for calcium and magnesium for drinking water are 75 and 30 mg/L respectively (BIS, 2012). In ground water, the calcium content generally exceeds the magnesium content in accordance with their relative abundance in rocks. All ground water samples collected from District Gautambudh Nagar fall within the maximum permissible limit of 200 mg/L of calcium and 100 mg/L of magnesium.

The concentration of sodium in the samples collected from District Gautambudh Nagar varies from 24 to 230 mg/L in private hand pumps, IM II hand pumps and bore wells/tube well. The Bureau of Indian Standards has not included sodium in drinking water standards. The high sodium values in the collected samples may be attributed to base-exchange phenomena and causes sodium hazard. Ground water with such high sodium is not suitable for irrigation purpose.

Potassium is an essential element for humans, plants and animals and derived in food chain mainly from vegetation and soil. The main sources of potassium in ground water include rain water, weathering of potash silicate minerals, use of potash fertilizers and use of surface water for irrigation. The concentration of potassium in the ground water samples collected from District Gautambudh Nagar varies from 1.0 to 53 mg/L in private hand pumps, IM II hand pumps and bore wells/tube well. The Bureau of Indian Standards has not included potassium in drinking water standards. However, the European Economic Community has prescribed guideline level of potassium at 10 mg/L in drinking water. As per EEC criteria, the ground water samples collected from bore well of village Bisrakh Jalalpur exceed the guideline level of 10 mg/L.

The concentration of chloride in the samples collected from District Gautambudh Nagar varies from 20 to 120 mg/L in private hand pumps, IM II hand pumps and bore wells/tube well. All samples were observed within the acceptable limit of 250 mg/L. The limits of chloride have been laid down primarily from taste considerations. A limit of 250 mg/L chloride has been recommended as acceptable limit and 1000 mg/L as the permissible limit for drinking water (BIS, 2012). However, no adverse health effects on humans have been reported from intake of waters containing even higher content of chloride.

The concentration of sulphate in the samples collected from District Gautambudh Nagar varies from 6.0 to 50 mg/L in private hand pumps, IM II hand pumps and bore wells/tube well. Bureau of Indian standard has prescribed 200 mg/L as the acceptable limit and 400 mg/L as the permissible limit for sulphate in drinking water. In the samples collected from District Gautambudh Nagar, none of the samples exceeded the maximum acceptable limit of 200 mg/L.

Nitrate content in drinking water is considered important for its adverse health effects and moderately toxicity. A limit of 45 mg/L has been prescribed by BIS (2012) for drinking water supplies. Its concentration above 45 mg/L may prove detriment to human health. In higher concentrations, nitrate may produce a disease known as methaemoglobinaemia (blue babies) which generally affects bottle-fed infants. Repeated heavy doses of nitrates on ingestion may also cause carcinogenic diseases. The nitrate content in the samples collected from District Gautambudh Nagar varies from 0 to 98 mg/L in private hand pumps, IM II hand pumps and bore wells/tube well. The nitrate concentration was observed more than permissible limit of 45 mg/L in ground water samples from IM II hand pump and bore well of village Bisrakh Jalalpur, which may be attributed to contamination by industrial/domestic waste disposal.

The presence of fluoride in ground water may be attributed to the localized effects of natural sources. The fluoride is present in soil strata due to the presence of geological formations like fluorspar, fluorapatite, ampheboles such as hornblinde, trimolite and mica. Weathering of alkali, silicate, igneous and sedimentary rocks specially shales contribute a major portion of fluorides to ground waters. In addition to natural sources, considerable amount of fluorides may be contributed due to man’s activities. Fluoride salts are commonly used in steel, aluminium, bricks and tile-industries. The fluoride containing insecticides and herbicides may be contributed through agricultural runoff. Phosphatic fertilizers, which are extensively used, often contain fluorides as impurity and these may increase levels of fluoride in soil. The accumulation of fluoride in soil eventually results in its leaching due to percolating water, thus increase fluoride concentration in ground water. The fluoride content in the ground water samples collected from District Gautambudh Nagar varies from 0.53 to 1.24 mg/L in private hand pumps, IM II hand pumps and bore wells/tube well. Ground water samples collected from private hand pump and IM II hand pump of Surajpur and tube well of village Momna Thal exceed the acceptable limit of 1.0 mg/L but within the permissible limit of 1.5 mg/L.

From the above discussion, it is clearly evident that in the ground water samples collected from District Gautambudh Nagar, the concentration of total dissolved solids was observed above the acceptable limit of 500 mg/L in the ground water samples collected from private hand pump of Surajpur, IM II hand pump of Bisrakh Jalalpur, Surajpur and bore wells/tube well of Bisrakh Jalalpur, Surajpur and Momna Thal of the district but none of the samples exceeded the maximum permissible limit of 2000 mg/L. None of the samples exceeded the maximum permissible limit of hardness of 600 mg/L. The concentration of nitrate exceeded the permissible limit in ground water samples collected from the IM II hand pump and bore well of village Bisrakh Jalalpur. The concentration of fluoride was observed to exceed the acceptable limit in ground water of village Surajpur. The violation of BIS limit could not be ascertained for sodium and potassium as no permissible limit for these constituents has been prescribed in BIS drinking water specifications. On the basis of above results, it can be inferred that ground water from private hand pumps have the problem of TDS and nitrate specially in the area of Bisrakh Jalalpur, which may be attributed to possible impact of effluents discharged into river Hindon on the ground water.

Bacteriological Parameters

In water quality control technology, the principal indicator of suitability of water for domestic, industrial or other uses is the coliform group of bacteria. The density of coliform group is the criteria for the extent of contamination and has been the basis for bacteriological water quality standard. Further, the presence of faecal colifirms in water is the indicator of a potential public health problem, because faecal matter is a source of pathogenic bacteria and viruses. The faecal coliform bacteria contaminate water through percolation from contamination sources (domestic sewage and septic tank) and also because of poor sanitary system. The indiscriminate land disposal of domestic waste on surface and improper disposal of solid waste further aggravate the problem of bacterial contamination in water. The collected samples from District Gautambudh Nagar were analysed for bacteriological parameters viz; Total Coliform and Faecal Coliform. The result of bacteriological analysis is given in Table 4.24. The result shows that the bacterial contamination was observed in four ground water samples of village Surajpur and Momna Thal of District Gautambudh Nagar.

Heavy Metals

Heavy metals in ground water have a considerable significance due to their toxicity and adsorption behaviour. Heavy metals are not biodegradable and enter the food chain through a number of pathways causing progressive toxicity due to the accumulation in human and animal organs during their life span on long term exposure to contaminated environments. Despite the presence of trace concentrations of Cr, Mn, Co, Cu and Zn in the aquatic environment, which is essential to a number of life processes, high concentrations of these metals become toxic. The major sources of heavy metals in ground water include weathering of rock minerals, discharge of sewage and other waste effluents on land and runoff water. The trace element data of ground water samples collected from the District Gautambudh Nagar is given in Table 4.25. The distribution of different metals is shown graphically in Fig. 4.15. The toxic effects of these elements and extent of their contamination in ground water is discussed in the following sections.

Iron (Fe): The concentration of iron in the ground water samples collected from District Gautambudh Nagar ranges from 0.045 to 13.480 mg/ in private hand pumps, IM II hand pumps and bore wells/tube well. The Bureau of Indian Standards has recommended 0.3 mg/L as the acceptable limit for iron in drinking water (BIS, 2012). WHO has prescribed 0.3 mg/L as the acceptability threshold value for iron (WHO, 2011). It is evident from the results that about 78% samples collected from the district exceed the acceptable limit of 0.3 mg/L. Highest concentration of iron 13.480 mg/L was observed in the ground water collected from private hand pump of Bisrakh Jalalpur. The higher concentration of iron in the almost all ground water samples may be attributed to leaching of industrial wastes flowing into the River Hindon.

It is a known fact that iron in trace amounts is essential for nutrition. High concentrations of iron generally cause inky flavour, bitter and astringent taste to water. Well water containing soluble iron remain clear while pumped out, but exposure to air causes precipitation of iron due to oxidation, with a consequence of rusty colour and turbidity. The objection to iron in the distribution system is not due to health reason but to staining of laundry and plumbing fixtures and appearance. Taste and order problems may be caused by filamentous organism that prey on iron compounds (frenothrix, gallionella and leptothrix are called iron bacteria), originating another consumer’s objection (red water). The presence of iron bacteria may clog well screens or develop in the distribution system, particularly when sulphate compounds in addition to iron may be subjected to chemical reduction.

Manganese (Mn): The concentration of manganese in the ground water samples collected from District Gautambudh Nagar ranges from 0.008 to 0.181 mg/L in private hand pumps, IM II hand pumps and bore wells/tubewell. Manganese is an essential trace nutrient for plants and animals, which does not occur naturally as a metal but is found in various salts and minerals frequently in association with iron compounds. Manganese may gain entry into the body by inhalation, consumption of food and through drinking water. A concentration of 0.1 mg/L has been recommended as an acceptable limit and 0.3 mg/L as the permissible limit for drinking water (BIS, 2012). WHO has prescribed 0.1 mg/L as the acceptability threshold value and 0.4 mg/L as health based value (WHO, 2011). It is evident from the results that about 56% of the samples collected from private hand pumps, IM II hand pumps and bore wells/tube well fall within the acceptable limit of 0.1 mg/L and none of the samples exceeds the maximum permissible limit of 0.3 mg/L. The presence of manganese above permissible limit of drinking water often imparts alien taste to water. It also has adverse effects on domestic uses and water supply structures.

Copper (Cu): The concentration of copper in the ground water samples collected from District Gautambudh Nagar ranges from 0.004 to 0.084 mg/L in private hand pumps, IM II hand pumps and bore wells/tube well. The Bureau of Indian Standards has recommended 0.05 mg/L as the acceptable limit and 1.5 mg/L as the permissible limit in the absence of alternate source (BIS, 2012). Beyond 0.05 mg/L the water imparts astringent taste and cause discoloration and corrosion of pipes, fittings and utensils. World Health Organization has recommended 2.0 mg/L as the provisional guideline value for drinking purpose (WHO, 2011). In the present investigation, two samples collected from private hand pump and IM II hand pump of village Bisrakh Jalalpur of District Gautambudh Nagar exceeds the acceptable limit of 0.05 mg/L.

Nickel (Ni): The concentration of nickel in the ground water samples collected from District Gautambudh Nagar ranges from ND to 0.172 mg/L in private hand pumps, IM II hand pumps and bore wells/tube well. The Bureau of Indian Standards has recommended 0.02 mg/L as the acceptable limit (BIS, 2012). World Health Organization has recommended 0.07 mg/L as the guideline value for drinking purposes (WHO, 2011). In this range it is not harmful in drinking water. Ground water samples collected from private hand pumps of Bisrakh Jalalpur, Surajpur and Momna Thal, IM II hand pump of Bisrakh Jalalpur and bore well of Surajpur exceed the BIS limit of 0.02 mg/L.

Chromium (Cr): The concentration of chromium in the ground water samples collected from District Gautambudh Nagar ranges from 0.010 to 0.058 mg/L in private hand pumps, IM II hand pumps and bore wells/tube well. A concentration of 0.05 mg/L has been recommended as an acceptable limit for drinking water (BIS, 2012). WHO has also prescribed 0.05 mg/L as the guideline value for drinking water (WHO, 2011). Three ground water samples collected from Bisrakh Jalalpur and Momna Thal exceeds the BIS limit of 0.05 mg/L.

Hexavalent chromium has a deleterious effect on the liver, kidney, and respiratory organs with hemorrhagic effects, dermatitis, and ulceration of the skin for chronic and subchronic exposure. Municipal wastewater release considerable amount of chromium into the environment. In the natural environment, Cr(+6) is likely to be reduced to Cr(+3), thereby reducing the toxic impact of chromium discharges. The pathways of chromium contribution to ground water are that the chromium containing industrial effluent discharged into stream, the hexavalent state chromium may be reduced to trivalent state and later adsorbed on the suspended particulate. In case, it could not be adsorbed, the chromium remain in the form of colloidal suspension, may precipitate and become part of stream sediment, from where it may reach to ground water through percolation containing shallow aquifers.

Lead (Pb): In the ground water samples collected from District Gautambudh Nagar, the concentration of lead ranges from ND to 0.233 mg/L in private hand pumps, IM II hand pumps and bore wells/tube well. The Bureau of Indian Standards has prescribed 0.01 mg/L lead as the desirable limit for drinking water (BIS, 2012). Beyond this limit, the water becomes toxic. WHO has also prescribed 0.01 mg/L as guideline value for drinking water (WHO, 2011). Six ground water samples collected from private hand pump, IM II hand pump and bore wells/tube well of the district exceed the BIS limit of 0.01 mg/L.

Lead is not considered an essential nutritional element and is a cumulative poison to humans. Acute lead poisoning is extremely rare. The typical symptoms of advanced lead poisoning are constipation, anemia, gastrointestinal disturbance, tenderness and gradual paralysis in muscles, specifically arms with possible cases of lethargy and moroseness. The major source of lead contamination is the combustion of fossil fuel. Lead is removed from the atmosphere by rain and falls back on the earth surface and seeps into the ground. Lead passes from the soil to water and to the plants and finally into the food chain. In drinking water it occurs primarily due to corrosion of lead pipes and solders, especially in areas of soft water. It may be noted that the use of soft water of slightly acidic pH and the use of lead pipes in service and domestic water lines may provide higher concentrations of lead at the consumers's tap, particularly when the water use is minimal in the household (overnight still water in pipes).

Cadmium (Cd): In the ground water samples collected from District Gautambudh Nagar, the concentration of cadmium ranges from ND to 0.057 mg/L in private hand pumps, IM II hand pumps and bore wells/tube well. The Bureau of Indian Standards has prescribed 0.003 mg/L cadmium as the acceptable limit for drinking water (BIS, 2012). Beyond this limit, the water becomes toxic. WHO has also prescribed 0.003 mg/L cadmium as the guideline value for drinking water (WHO, 2011). The drinking water having more than 3 μg/L of cadmium can cause bronchitis, emphysema, anaemia and renal stone formation in animals. Seven ground water samples collected from district exceed the BIS limit of 0.003 mg/L.

Zinc (Zn): The concentration of zinc in the ground water samples collected from District Gautambudh Nagar ranges from 0.042 to 0.586 mg/L in private hand pumps, IM II hand pumps and bore wells/tube well. The Bureau of Indian Standards has prescribed 5.0 mg/L zinc as the acceptable limit and 15 mg/L as the permissible limit for drinking water (BIS, 2012). WHO has prescribed 3.0 mg/L as the guideline value for drinking water (WHO, 2011). All the samples were found within the desirable limit prescribed by BIS (2012) and WHO (2011).

Arsenic (As): In the ground water samples collected from District Gautambudh Nagar, the concentration of arsenic was not detected. Ground water is expected to contain higher arsenic concentrations than surface water. Because of its presence in geological materials, arsenic can be traced in water as originated by natural processes or by industrial activities – industrial waste, arsenical pesticides and smelting operations. Generally, arsenic found in two state – As(III) and As(V) in ground water. As(III) compounds are more toxic than As(V) compounds. Arsenic compounds are skin and lung carcinogens in humans. The Bureau of Indian Standards has prescribed 0.01 mg/L arsenic as the acceptable limit and 0.05 mg/L as the permissible limit for drinking water (BIS, 2012). Beyond this limit, the water becomes toxic. WHO has prescribed 0.01 mg/L arsenic as the guideline value for drinking water (WHO, 2011). In the present investigation, all the ground water samples collected from District Gautambudh Nagar were found within the acceptable limit prescribed by BIS (2012).

From the above results, it is quite clear that the presence of heavy metals has been recorded in many location and the water quality standards have been violated for iron (7 samples), manganese (4 samples), copper (2 samples), nickel (5 samples), chromium (3 samples), lead (6 samples) and cadmium (7 samples) out of total 9 samples collected from private hand pumps, IM II hand pumps and bore wells/tube well of District Gautambudh Nagar.

Pesticides

The analysis of nine organo-chlorinated pesticides (Aldrin, α-BHC, β-BHC, γ-BHC, δ-BHC, DDD, DDE, Endosulphan and Methoxychlor) was carried out in ground water samples from IM II hand pump of Bisrakh Jalalppur and Surajpur of District Gautambudh Nagar but none of the pesticide has been detected in the analysed samples.

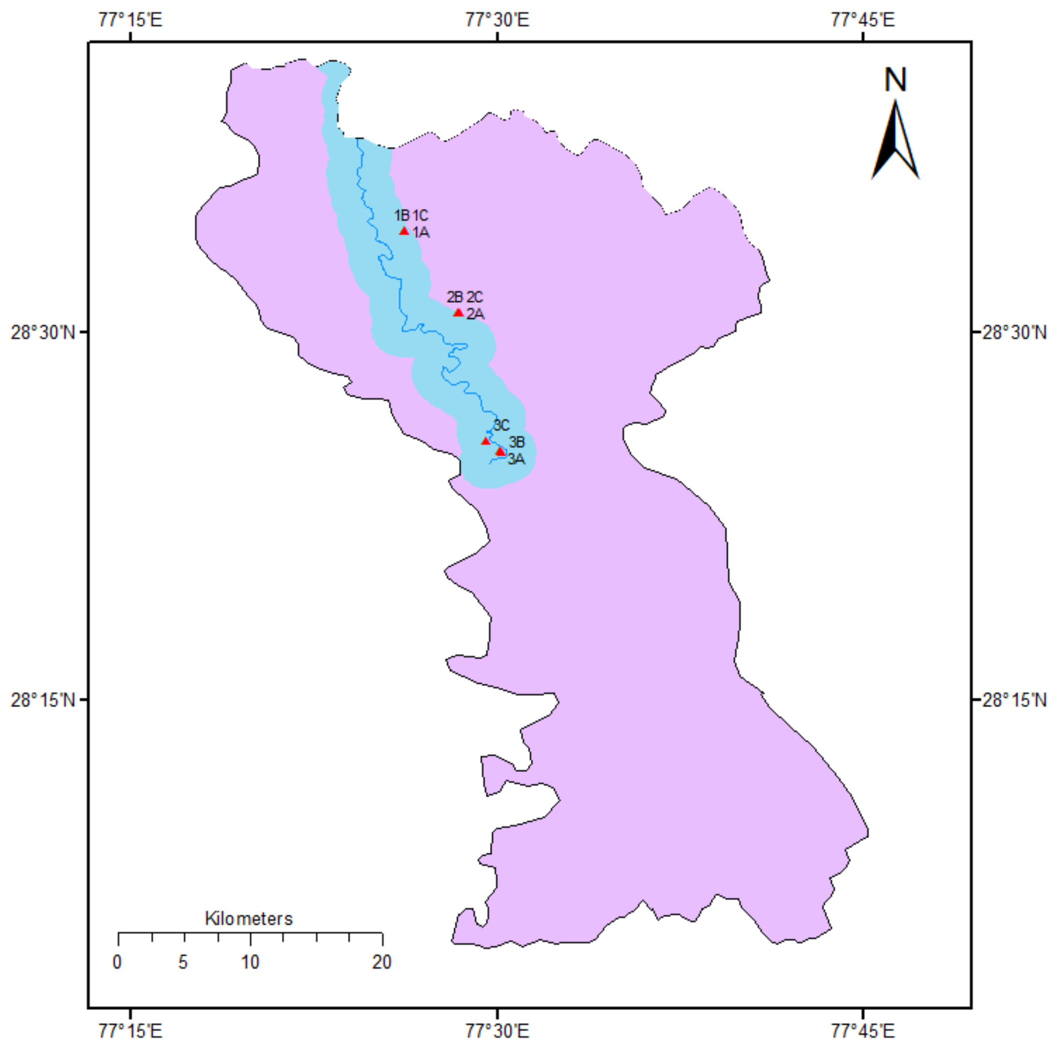


Fig. 4.14 Ground Water Sampling Locations in District Gautambudh Nagar in Two km Buffer Zone of River Hindon

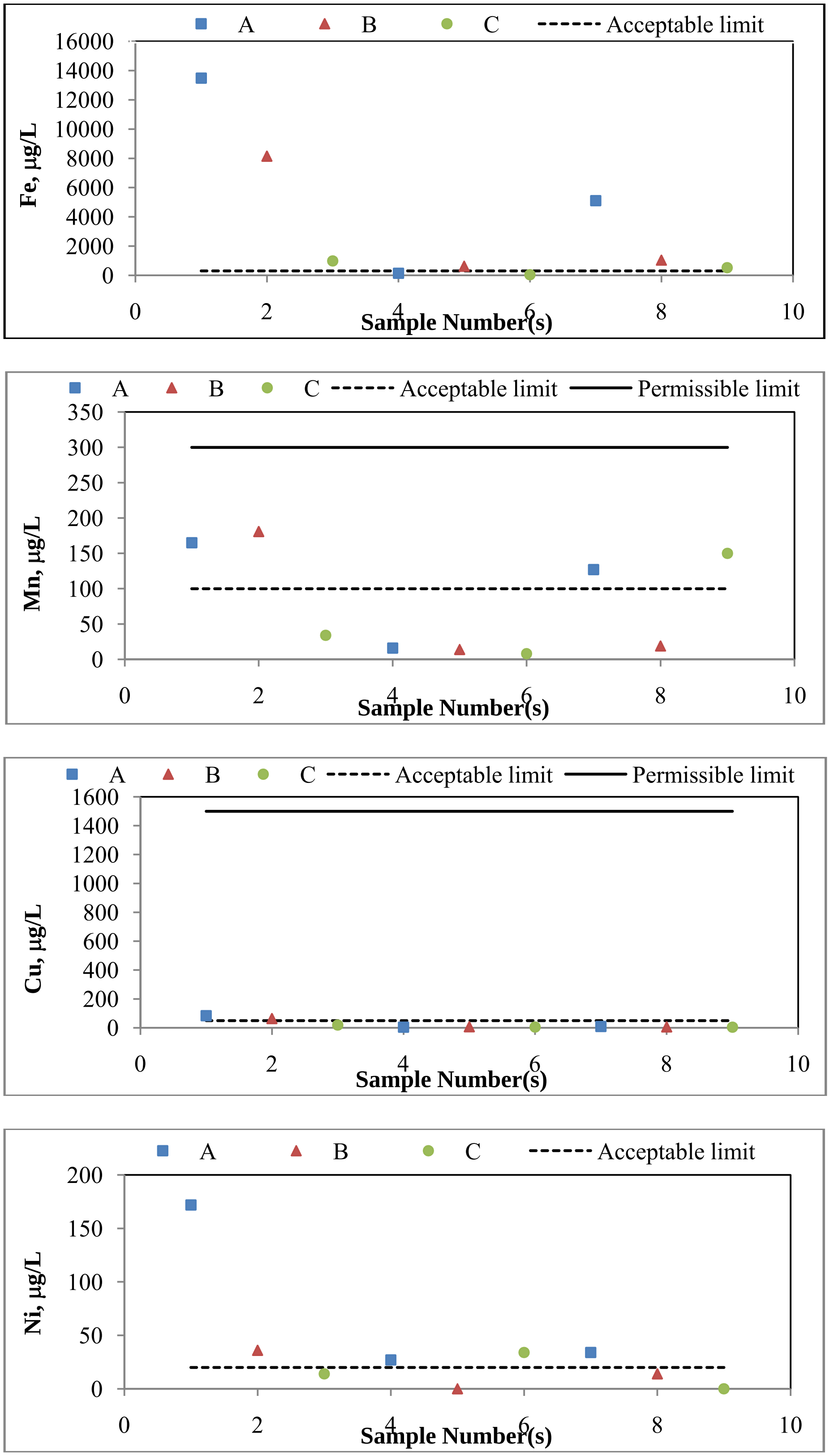


Fig. 4.15 Distribution of Trace Elements in Ground Water of District Gautambudh Nagar

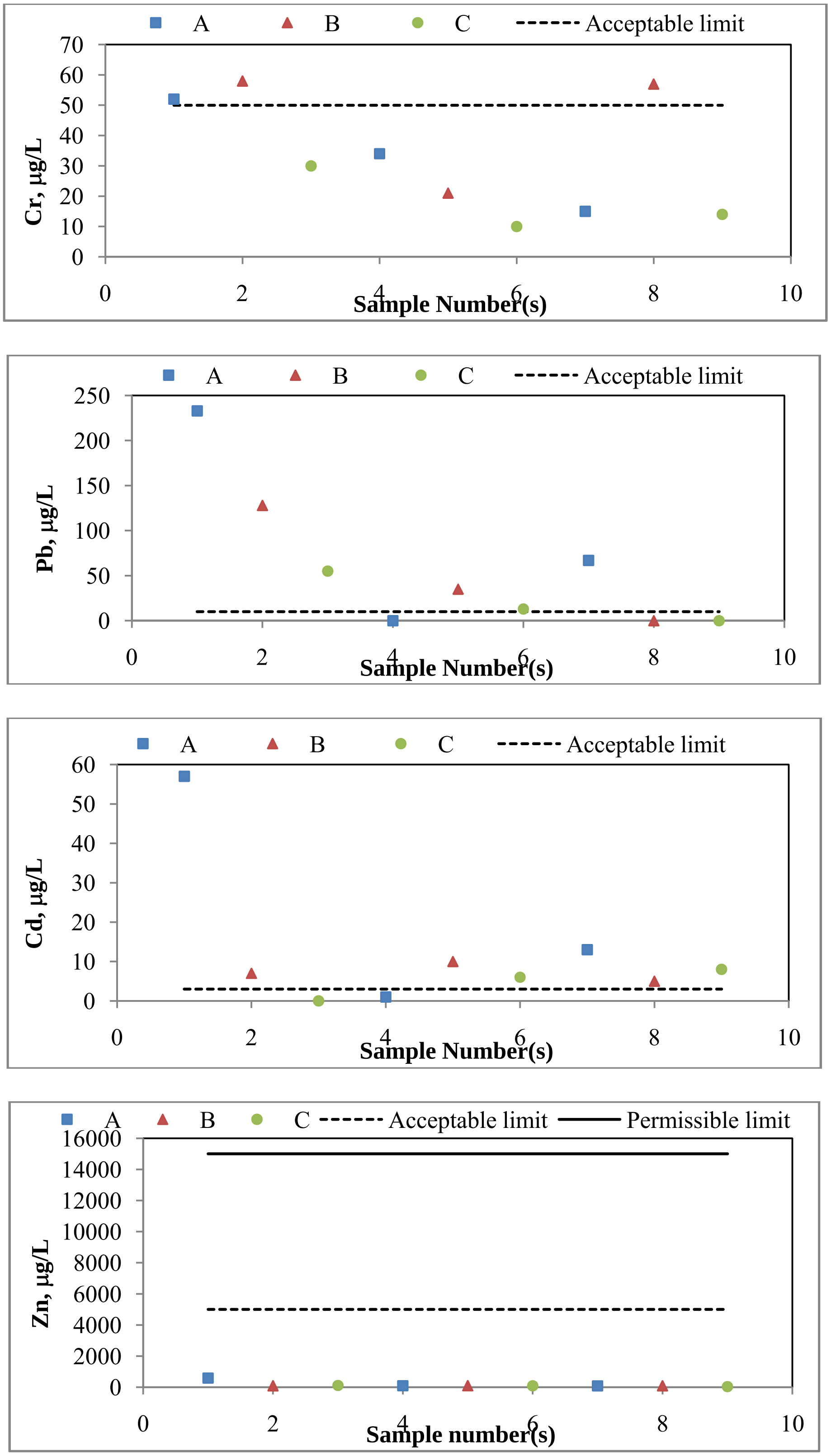


Fig. 4.15 (Contd.) Distribution of Trace Elements in Ground Water of District Gautambudh Nagar

Table 4.23 Hydro-chemical Data of Ground Water Samples of District Gautambudh Nagar (March 2013)

S.No.	Sample ID	Location	Source	Depth	pH	EC	TDS	Alk	Hard	Na	K	Ca	Mg	HCO3	Cl	SO4	NO3	PO4	F	BOD	COD
				m		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1	GBN-1A	Bisrakh Jalalpur	HP	49	7.7	728	466	252	233	41	6.4	39	33	307	20	10	5.9	0.06	0.68	1.2	3.2
2	GBN-1B	Bisrakh Jalalpur	IM II	37	7.2	1135	726	216	381	60	7.2	82	43	264	120	50	98	0.08	0.56	0.9	4.6
3	GBN-1C	Bisrakh Jalalpur	BW	30	7.5	1100	704	304	230	75	53	36	34	371	66	6.0	62	0.06	0.71	1.2	5.2
4	GBN-2A	Surajpur	HP	46	7.4	1552	993	456	181	230	7.8	38	21	556	108	16	13	0.08	1.19	1.2	3.4
5	GBN-2B	Surajpur	IM II	37	8.0	1288	824	406	64	220	4.4	14	7.0	495	60	8.5	12	0.06	1.24	0.8	2.2
6	GBN-2C	Surajpur	BW	37	7.8	1245	797	380	108	204	3.3	17	16	464	64	9.0	18	0.06	0.96	0.8	3.2
7	GBN-3A	Momna Thal	HP	37	7.9	446	285	136	149	24	3.0	30	18	166	24	14	3.4	0.08	0.53	1.0	2.6
8	GBN-3B	Momna Thal	IM II	37	7.7	500	320	146	174	28	3.2	35	21	178	36	16	1.2	0.08	0.59	1.2	3.0
9	GBN-3C	Momna Thal	TW	9	7.6	920	589	304	291	51	1.0	54	38	371	60	10	0	0.04	1.22	0.6	2.2
		Minimum			7.2	446	285	136	64	24	1.0	14	7.0	166	20	6.0	0	0.04	0.53	0.6	2.2
		Maximum			8.0	1552	993	456	381	230	53	82	43	556	120	50	98	0.08	1.24	1.2	5.2
		Mean			7.6	990	634	289	201	104	10	38	26	352	62	16	24	0.07	0.85	1.0	3.3

Table 4.24 Bacteriological Data of Ground Water Samples of District Gautambudh Nagar (March 2013)

S.No.	Sample ID	Location	Source	Depth	Total Coliform	Fecal Coliform
				m	per 100 ml	per 100 ml
1	GBN-1A	Bisrakh Jalalpur	HP	49	<3	<3
2	GBN-1B	Bisrakh Jalalpur	IM II	37	<3	<3
3	GBN-1C	Bisrakh Jalalpur	BW	30	<3	<3
4	GBN-2A	Surajpur	HP	46	240	7
5	GBN-2B	Surajpur	IM II	37	23	<3
6	GBN-2C	Surajpur	BW	37	<3	<3
7	GBN-3A	Momna Thal	HP	37	23	<3
8	GBN-3B	Momna Thal	IM II	37	23	<3
9	GBN-3C	Momna Thal	TW	9	<3	<3

Table 4.25 Trace Element Data of Ground Water Samples of District Gautambudh Nagar (March 2013)

S.No.	Sample ID	Location	Source	Depth	Fe	Mn	Cu	Ni	Cr	Pb	Cd	Zn	As
				m	μg/L	μg/L	μg/L	μg/L	μg/L	μg/L	μg/L	μg/L	μg/L
1	GBN-1A	Bisrakh Jalalpur	HP	49	13480	165	84	172	52	233	57	586	ND
2	GBN-1B	Bisrakh Jalalpur	IM II	37	8145	181	64	36	58	128	7.0	92	ND
3	GBN-1C	Bisrakh Jalalpur	BW	30	985	34	19	14	30	55	ND	112	ND
4	GBN-2A	Surajpur	HP	46	137	16	4.0	27	34	ND	1.0	88	ND
5	GBN-2B	Surajpur	IM II	37	624	14	7.0	ND	21	35	10	96	ND
6	GBN-2C	Surajpur	BW	37	45	8.0	5.0	34	10	13	6.0	92	ND
7	GBN-3A	Momna Thal	HP	37	5103	127	9.0	34	15	67	13	83	ND
8	GBN-3B	Momna Thal	IM II	37	1042	19	6.0	14	57	ND	5.0	90	ND
9	GBN-3C	Momna Thal	TW	9	521	150	4.0	ND	14	ND	8.0	42	ND
		Minimum			45	8.0	4.0	ND	10	ND	1.0	42	ND
		Maximum			13480	181	84	172	58	233	57	586	ND
		Mean			3342	79	22	47	32	89	13	142	ND

4.3 Water Quality Index

Water Quality Index (WQI) is an important parameter for demarcating ground water quality and its suitability for drinking purposes (Tiwari and Mishra, 1985; Singh, 1992; Subba Rao, 1997; Mishra and Patel, 2001; Naik and Purohit, 2001; Avvannavar and Shrihari, 2008). It is defined as a technique of rating that provides the composite influence of individual water quality parameters on the overall quality of water for human consumption. The standards for drinking purposes as recommended by BIS (2012) and WHO (2011) have been considered for the calculation of WQI. For computing WQI, three steps are followed. In the first step, each of the 10 parameters (TDS, HCO_3, Cl, SO_4, NO_3, F, Ca, Mg, Na and K) has been assigned a weight (w_i) according to its relative importance in the overall quality of water for drinking purposes.

The maximum weight of 5 has been assigned to the parameters like nitrate, total dissolved solids, chloride, fluoride and sulphate due to their major importance in water quality assessment (Srinivasamoorthy et al., 2008). Bicarbonate is given the minimum weight of 1 as it plays an insignificant role in the water quality assessment. Other parameters like calcium, magnesium, sodium and potassium were assigned weight between 1 and 5 depending on their importance in water quality determination. In the second step, the relative weight (W_i) is computed from the following equation:

$$W_i = w_i / \sum_{i=1}^{n} w_i$$

Where W_i is relative weight, w_i is weight of each parameter and n is the number of parameters.

Calculated relative weight (W_i) values of each parameter are given in Table 4.26.

Table 4.26 Relative Weight of Chemical Parameters

Chemical parameters	Indian Standard (BIS, 2012)	Weight (wi)	Relative weight $W_i = w_i / \sum_{i=1}^{n} w_i$
Total dissolved solids (mg/L)	500	5	0.132
Bicarbonate (mg/L)	244	1	0.026
Chloride (mg/L)	250	5	0.132
Sulphate (mg/L)	200	5	0.132
Nitrate (mg/L)	45	5	0.132
Fluoride (mg/L)	1.0	5	0.132
Calcium (mg/L)	75	3	0.079
Magnesium (mg/L)	30	3	0.079
Sodium (mg/L)	200	4	0.105
Potassium (mg/L)	10	2	0.053

In the third step, a quality rating scale (q_i) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the BIS (2012) and the result multiplied by 100.

$$q_i = \left(\frac{C_i}{S_i}\right) x\ 100$$

Where q_i is quality rating, C_i is concentration of each chemical parameter in each water sample (mg/L) and S_i is drinking water standard for each chemical parameter (mg/L) according to the guidelines prescribed by BIS (2012).

For computing the WQI, the SI is first determined for each chemical parameter, which is then used to determine the WQI as per the following equation:

$$SI_i = W_i \text{ x } q_i$$

$$WQI = \sum_{i=1}^{n} SI_i$$

Where SI_i is sub-index of i^{th} parameter, q_i is rating based on concentration of i^{th} parameter and n is the number of parameters.

Water quality types can be determined on the basis of WQI. The WQI range and type of water can be classified as follows (Vasanthavigar et al., 2010)

Range	Type of water
<50	Excellent water
50-100.1	Good water
100-200.1	Poor water
200-300.1	Very poor water
>300	Water unsuitable for drinking purposes

The Water Quality Index of various drinking water of District Saharanpur, Muzaffarnagar, Shamli, Meerut, Baghpat, Ghaziabad and Gautambudh Nagar are given in Tables 4.27 to 4.33.

Table 4.27 Water Quality Index of Various Drinking Water Sources of District Saharanpur

S.No.	Village	Source	Depth (m)	Sample ID	WQI	Type of Water
1.	Sarda Heri	HP	31	SRE-1A	42.84	Excellent water
2.		IM II	37	SRE-1B	50.15	Good water
3.		TW	137	SRE-1C	38.16	Excellent water
4.	Ibrahimpur	HP	21	SRE-2A	37.26	Excellent water
5.		IM II	37	SRE-2B	44.12	Excellent water
6.	Pali	HP	46	SRE-3A	35.57	Excellent water
7.		IM II	37	SRE-3B	32.39	Excellent water
8.		TW	56	SRE-3C	38.48	Excellent water
9.	Gagalhedi	HP	18	SRE-4A	44.85	Excellent water
10.		IM II	37	SRE-4B	37.70	Excellent water
11.		TW	40	SRE-4C	37.32	Excellent water
12.	Khazoori Akbarpur	HP	20	SRE-5A	48.51	Excellent water

13.		IM II	37	SRE-5B	32.52	Excellent water
14.	Ghoghriki	HP	21	SRE-6A	56.21	Good water
15.		IM II	37	SRE-6B	56.80	Good water
16.	Paragpur	HP	21	SRE-7A	167.97	Poor water
17.		IM II	37	SRE-7B	113.48	Poor water
18.	Hasanpur banaswa	HP	26	SRE-8A	72.40	Good water
19.		IM II	37	SRE-8B	50.91	Good water
20.	Kapasa	HP	12	SRE-9A	92.02	Good water
21.		IM II	37	SRE-9B	32.71	Excellent water
22.	Tapri	HP	24	SRE-10A	64.65	Good water
23.		IM II	37	SRE-10B	50.76	Good water
24.		TW	55	SRE-10C	51.94	Good water
25.	Shekhpura kadim	HP	20	SRE-11A	214.46	Very poor water
26.		IM II	37	SRE-11B	29.44	Excellent water
27.	Lakhnour	HP	20	SRE-12A	116.27	Poor water
28.		IM II	37	SRE-12B	31.74	Excellent water
29.		TW	46	SRE-12C	38.09	Excellent water
30.	Mubarakpur	HP	14	SRE-13A	48.27	Excellent water
31.		IM II	37	SRE-13B	38.66	Excellent water
32.	Nandi Must.	HP	24	SRE-14A	59.30	Good water
33.		IM II	37	SRE-14B	47.52	Excellent water
34.	Baleda Junardar	HP	24	SRE-15A	41.82	Excellent water
35.		IM II	37	SRE-15B	35.04	Excellent water
36.	Rasoolpur kheri	HP	21	SRE-16A	47.37	Excellent water
37.		IM II	37	SRE-16B	27.10	Excellent water
38.	Jainpur	HP	21	SRE-17A	65.47	Good water
39.		IM II	37	SRE-17B	41.63	Excellent water
40.	Sadhauli Hariya	HP	31	SRE-18A	60.94	Good water
41.		IM II	37	SRE-18B	40.09	Excellent water
42.	Tanshipur	HP	37	SRE-19A	72.97	Good water
43.		IM II	37	SRE-19B	53.51	Good water
44.		TW	56	SRE-19C	63.87	Good water
45.	Shitala Khera	HP	38	SRE-20A	66.20	Good water
46.		IM II	37	SRE-20B	47.13	Excellent water
47.		TW	46	SRE-20C	42.13	Excellent water
48.	Maheshpur	HP	37	SRE-21A	64.46	Good water
49.		IM II	37	SRE-21B	48.03	Excellent water
50.		TW	55	SRE-21C	37.53	Excellent water
51.	Mahmoodpur	HP	37	SRE-22A	32.90	Excellent water
52.		IM II	61	SRE-22B	36.08	Excellent water
53.	Bhataul	HP	24	SRE-23A	56.14	Good water
54.		IM II	37	SRE-23B	45.27	Excellent water
55.		BW	49	SRE-23B	44.16	Excellent water
56.	Banhera Khas	HP	14	SRE-24A	37.10	Excellent water
57.		IM II	37	SRE-24B	33.87	Excellent water
58.	Chandpur Kayasth	HP	20	SRE-25A	46.63	Excellent water
59.		IM II	37	SRE-25B	33.35	Excellent water
60.		BW	34	SRE-25C	31.49	Excellent water
61.	Palauli	HP	15	SRE-26A	43.87	Excellent water
62.		IM II	37	SRE-26B	41.04	Excellent water
63.	Sanpla Khatri	HP	7	SRE-27A	98.64	Good water
64.		IM II	37	SRE-27B	45.63	Excellent water
65.		BW	34	SRE-27C	38.24	Excellent water

66.	Matauli	HP	15	SRE-28A	86.10	Good water
67.		IM II	37	SRE-28B	33.44	Excellent water
68.		BW	46	SRE-28C	33.41	Excellent water

HP – Private Hand Pump; IM II – India Mark II; TW – Tube Well; BW – Bore Well

Table 4.28 Water Quality Index of Various Drinking Water Sources in District Muzaffarnagar

S.No.	Village	Source	Depth (m)	Sample ID	WQI	Type of Water
1.	Sujru	IM II	12	MZN-1B	38.21	Excellent water
2.		TW	30	MZN-1C	31.69	Excellent water
3.	Lachhera	HP	21	MZN-2A	60.16	Good water
4.		IM II	37	MZN-2B	31.44	Excellent water
5.		TW	38	MZN-2C	29.21	Excellent water
6.	Purbaliyan	HP	11	MZN-3A	72.31	Good water
7.		IM II	46	MZN-3B	84.51	Good water
8.		TW	67	MZN-3C	31.63	Excellent water
9.	Jeewna	HP	14	MZN-4A	115.07	Poor water
10.		IM II	46	MZN-4B	33.75	Excellent water
11.		TW	24	MZN-4C	29.04	Excellent water
12.	Kilasa (Kitas)	HP	17	MZN-5A	58.83	Good water
13.		IM II	76	MZN-5B	39.67	Excellent water
14.		TW	61	MZN-5C	49.33	Excellent water
15.	Rohana Khurd	HP	14	MZN-6A	43.60	Excellent water
16.		IM II	37	MZN-6B	34.61	Excellent water
17.		TW	38	MZN-6C	36.69	Excellent water
18.	Didaheri	HP	18	MZN-7A	73.64	Good water
19.		IM II	34	MZN-7B	30.26	Excellent water
20.		TW	32	MZN-7C	38.50	Excellent water
21.	Kasoli	HP	24	MZN-8A	48.18	Excellent water
22.		IM II	55	MZN-8B	28.85	Excellent water
23.		TW	38	MZN-8C	41.45	Excellent water
24.	Nagla Rai	HP	6	MZN-9A	229.38	Very poor water
25.		IM II	38	MZN-9B	41.04	Excellent water
26.		TW	38	MZN-9C	55.87	Good water
27.	Ladwa	HP	9	MZN-10A	91.90	Good water
28.		IM II	49	MZN-10B	70.01	Good water
29.		TW	27	MZN-10C	68.29	Good water
30.	Atali	HP	14	MZN-11A	62.52	Good water
31.		IM II	24	MZN-11B	64.34	Good water
32.	Hadoli	HP	15	MZN-12A	86.56	Good water
33.		IM II	40	MZN-12B	62.14	Good water
34.		TW	46	MZN-12C	38.16	Excellent water
35.	Titawi	HP	17	MZN-13A	55.57	Good water
36.		IM II	46	MZN-13B	40.91	Excellent water
37.	Inchauli	HP	21	MZN-14A	35.15	Excellent water
38.		IM II	55	MZN-14B	29.94	Excellent water
39.		TW	21	MZN-14C	42.96	Excellent water
40.	Rampur	HP	18	MZN-15A	130.24	Poor water
41.		IM II	46	MZN-15B	35.48	Excellent water
42.		TW	61	MZN-15C	44.66	Excellent water
43.	Chandsina	HP	17	MZN-16A	144.02	Poor water
44.		IM II	46	MZN-16B	35.42	Excellent water

45.		TW	61	MZN-16C	37.57	Excellent water
46.	Budhana Khadar	HP	31	MZN-17A	68.70	Good water
47.		IM II	64	MZN-17B	47.33	Excellent water
48.		BW(PS)	104	MZN-17C	41.07	Excellent water

HP – Private Hand Pump; IM II – India Mark II; TW – Tube Well; BW(PS) – Bore Well Piped Water Supply

Table 4.29 Water Quality Index of Various Drinking Water Sources of District Shamli

S.No.	Village	Source	Depth (m)	Sample ID	WQI	Type of Water
1.	Lisarh	HP	41	SML-1A	44.37	Excellent water
2.		IM II	73	SML-1B	44.36	Excellent water
3.		TW	73	SML-1C	62.04	Good water
4.	Bahawari	HP	70	SML-2A	46.85	Excellent water
5.		IM II	73	SML-2B	40.20	Excellent water
6.		TW	82	SML-2C	51.45	Good water
7.	Sunna	HP	58	SML-3A	43.56	Excellent water
8.		IM II	55	SML-3B	45.35	Excellent water
9.		TW	70	SML-3C	49.86	Excellent water
10.	Bhanera	HP	30	SML-4A	62.41	Good water
11.		IM II	61	SML-4B	73.59	Good water
12.		TW	58	SML-4C	48.44	Excellent water
13.	Kudana	HP	30	SML-5A	62.89	Good water
14.		IM II	73	SML-5B	56.99	Good water
15.		TW	53	SML-5C	58.38	Good water
16.	Kheri Bairagi	HP	62	SML-6A	58.09	Good water
17.		IM II	49	SML-6B	51.30	Good water
18.		TW	70	SML-6C	52.66	Good water
19.	Bantikhera	HP	21	SML-7A	101.01	Poor water
20.		IM II	49	SML-7B	55.01	Good water
21.		TW	76	SML-7C	53.42	Good water
22.	Kairi	HP	30	SML-8A	63.19	Good water
23.		IM II	61	SML-8B	59.86	Good water
24.		BW(PS)	183	SML-8C	34.14	Excellent water
25.	Chandenamal	HP	14	SML-9A	78.17	Good water
26.		IM II	30	SML-9B	36.07	Excellent water
27.		BW(PS)	122	SML-9C	32.33	Excellent water
28.	Dabheri	HP	9	SML-10A	68.32	Good water
29.		IM II	30	SML-10B	37.61	Excellent water
30.		TW	61	SML-10C	36.64	Excellent water
31.	Jalalabad (R)	HP	21	SML-11A	62.40	Good water
32.		IM II	34	SML-11B	87.52	Good water
33.		BW(PS)	98	SML-11C	36.76	Excellent water
34.	Harad Fatehpur	HP	27	SML-12A	51.87	Good water
35.		IM II	61	SML-12B	48.63	Excellent water
36.		TW	76	SML-12C	45.76	Excellent water
37.	Raipur	HP	24	SML-13A	117.39	Poor water
38.		IM II	55	SML-13B	38.62	Excellent water
39.		TW	61	SML-13C	32.22	Excellent water
40.	Masavi	HP	24	SML-14A	66.81	Good water
41.		IM II	40	SML-14B	56.70	Good water

HP – Private Hand Pump; IM II – India Mark II; TW – Tube Well; BW(PS) – Bore Well Piped Water Supply

Table 4.30 Water Quality Index of Various Drinking Water Sources of District Meerut

S.No.	Village	Source	Depth (m)	Sample ID	WQI	Type of Water
1.	Baparsi	HP	30	MTC-1A	36.68	Excellent water
2.		IM II	37	MTC-1B	43.67	Excellent water
3.		IM II	37	MTC-1B2	54.44	Good water
4.		TW	55	MTC-1C	33.46	Excellent water
5.	Dhilaura	HP	9	MTC-2A	111.60	Poor water
6.		IM II	37	MTC-2B	51.87	Good water
7.		TW	15	MTC-2C	56.82	Good water
8.	Alamgirpur Faridpur	HP	61	MTC-3A	32.23	Excellent water
9.		IM II	37	MTC-3B	34.07	Excellent water
10.		TW	12	MTC-3C	36.72	Excellent water
11.	Nahli	HP	18	MTC-4A	53.14	Good water
12.		IM II	37	MTC-4B	38.38	Excellent water
13.		TW	67	MTC-4C	32.26	Excellent water
14.	Pithlokar	HP	12	MTC-5A	78.33	Good water
15.		IM II	37	MTC-5B	39.77	Excellent water
16.		TW	49	MTC-5C	33.79	Excellent water

HP – Private Hand Pump; IM II – India Mark II; TW – Tube Well

Table 4.31 Water Quality Index of Various Drinking Water Sources of District Baghpat

S.No.	Village	Source	Depth (m)	Sample ID	WQI	Type of Water
1.	Khaprana	HP	14	BPM-1A	100.40	Poor water
2.		IM II	37	BPM-1B	122.52	Poor water
3.	Galheta	HP	34	BPM-2A	85.30	Good water
4.		IM II	37	BPM-2B	39.81	Excellent water
5.	Himmatpur	HP	52	BPM-3A	71.17	Good water
6.		IM II	61	BPM-3B	43.91	Excellent water
7.		TW	79	BPM-3C	51.05	Good water
8.	Gangnoli	HP	43	BPM-4A	30.13	Excellent water
9.		IM II	61	BPM-4B	39.77	Excellent water
10.		TW	55	BPM-4C	46.36	Excellent water
11.	Bamnauli	HP	37	BPM-5A	43.36	Excellent water
12.		IM II	43	BPM-5B	54.02	Good water
13.		BW(PS)	122	BPM-5C	49.89	Excellent water
14.	Barnawa	HP	30	BPM-6A	83.78	Good water
15.		IM II	37	BPM-6B	72.93	Good water

HP – Private Hand Pump; IM II – India Mark II; TW – Tube Well; BW(PS) – Bore Well Piped Water Supply

Table 4.32 Water Quality Index of Various Drinking Water Sources of District Ghaziabad

S.No.	Village	Source	Depth (m)	Sample ID	WQI	Type of Water
1.	Surana	HP	24	GZB-1A	270.21	Very poor water
2.		IM II	43	GZB-1B	58.65	Good water
3.		BW(PS)	76	GZB-1C	56.47	Good water

4.	Bhanera	HP	21	GZB-2A	56.43	Good water
5.		IM II	37	GZB-2B	50.71	Good water

HP – Private Hand Pump; IM II – India Mark II; BW(PS) – Bore Well Piped Water Supply

Table 4.33 Water Quality Index of Various Drinking Water Sources of Gautambudh Nagar

S.No.	Village	Source	Depth (m)	Sample ID	WQI	Type of Water
1.	Bisrakh Jalalpur	HP	49	GBN-1A	45.09	Excellent water
2.		IM II	37	GBN-1B	92.06	Good water
3.		BW	30	GBN-1C	95.92	Good water
4.	Surajpur	HP	46	GBN-2A	81.92	Good water
5.		IMII	37	GBN-2B	66.05	Good water
6.		BW	37	GBN-2C	64.60	Good water
7.	Momna Thal	HP	37	GBN-3A	29.42	Excellent water
8.		IM II	37	GBN-3B	32.91	Excellent water
9.		TW	9	GBN-3C	56.76	Good water

HP – Private Hand Pump; IM II – India Mark II; TW – Tube Well; BW – Bore Well

5.0 CONCLUSIONS AND RECOMMENDATIONS

From the analysis of the ground water samples collected from various drinking water sources (Private Hand Pumps, IM II Hand Pumps and Tube Wells / Bore Wells), the following villages, falling within 2 km buffer zone of various rivers flowing in the area, have been identified which are not conforming to Drinking Water Specifications prescribed by BIS (2012). The shallow aquifers (Private Hand Pumps) are more prone to nitrate contamination due to improper waste disposal practices. The presence of trace elements has also been recorded at many location and the water quality standards have been violated for various metals. The presence of chlorinated pesticides (γ-BHC and Methoxychlor) in some ground water samples is a cause of serious concern and need further detailed investigations.

S.No.	District	Affected villages falling within 2 km buffer zone of River Hindon-Kali-Krishni	General Parameters exceeding permissible limits prescribed by BIS (2012)
1.	Saharanpur	Paragpur	Hardness, Nitrate, Fluoride
		Kapasa	Hardness
		Hasanpur Banaswa	Nitrate
		Shekhpura Kadim	Hardness, Nitrate
		Lakhnour	Nitrate
		Shitala Khera	Nitrate
		Sanpla Khatri	Hardness
2.	Muzaffarnagar	Purbaliyan	Nitrate
		Nagla Rai	Hardness, Nitrate
		Jeewna	Nitrate
		Didaheri	Nitrate
		Hadoli	Nitrate
		Ladwa	Hardness
		Rampur	Hardness, Nitrate
3.	Shamli	Chandenamal	Hardness
		Harad Fatehpur	Nitrate
		Lisarh	Fluoride
		Jalalabad	Fluoride
4.	Meerut	Dhilaura	Nitrate
		Pithlokar	Nitrate
5.	Baghpat	Khaprana	Nitrate, Fluoride
		Galheta	Nitrate
		Barnawa	Nitrate
6.	Ghaziabad	Surana	Nitrate, Fluoride
7.	Gautambudh Nagar	Bisrakh Jalalpur	Nitrate
		Surajpur	Fluoride
		Momna Thal	Fluoride

The affected villages of different Districts should be given priority for supply of safe drinking water and this should be extended to other villages in a phased manner. Safe water can be provided to the affected villages by opting following schemes:

i) **Provision of alternate source of water -** It may be possible to get a safe water source in the vicinity by drawing the water from deeper aquifers.

ii) **Transporting water from a distant source through piped water supply -** This may lead to lasting benefits, but initial cost will be high.

iii) **Rainwater harvesting -** There are two ways in which rainwater harvesting can be used as a solution to the problem of fluoride in ground water. Individual household-roof rainwater harvesting and container storage can provide potable water to the affected families.

iv) In the absence of alternate safe source of water, the water with excessive undesirable constituents must be treated with specific treatment process before its use for human consumption. The following treatment options may be attempted:

  a) Hardness (temporary/bicarbonate) in excess of permissible limits can be removed by lime softening process. This will result in reduction of TDS also and will provide most economically viable solution. Membrane based (RO) technology based on split flow can also be used to achieve desired TDS values.

  b) Nitrate in excess of permissible limits can be removed by ion exchange resins in chloride form or by continuous backwash filters utilizing natural (biological) process of converting nitrate to nitrogen.

  c) The heavy metals, viz., Fe, Mn, Cr, Ni, Pb and Cd can be removed by opting sulfex process which is based on precipitating these metals with sodium sulfide or iron sulfide along with hardness removal.

v) The ground water abstraction sources and their surroundings should be properly maintained to ensure hygienic conditions and no sewage or polluted water should be allowed to percolate directly to ground water aquifer.

vi) Proper cement platforms should be constructed surrounding the ground water abstraction sources to avoid direct well head pollution.

vii) The surrounding surface area of the ground water abstraction structures should be frequently chlorinated by use of bleaching power.

viii) The hand pumps, which have been identified as having suspected water quality should be painted red to indicate and warn the public that the water drawn from the source is not fit for human consumption.

ix) The ground water drawn from hand pumps should be properly chlorinated to eradicate the presence of bacterial contamination.

x) The untreated sewage and sewerage flowing in various open drains are one of the causes of ground water quality deterioration. Proper underground sewage system must be laid in all inhabited areas and the untreated sewage and industrial wastes should not be allowed to flow in open drains to avoid any further contamination of ground water.

xi) A proper system of collection and transportation of domestic waste should be developed. Land fill site(s) should be identified and it must be scientifically designed. Ground water quality near land fill sites should be regularly monitored.

xii) The mass awareness should be generated about quality of water, its effect on human health and responsibilities of public to safeguard water resources.

xiii) The study should be extended to other villages of the districts covering all habitations to have a proper assessment of ground water quality and extent of contamination.

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