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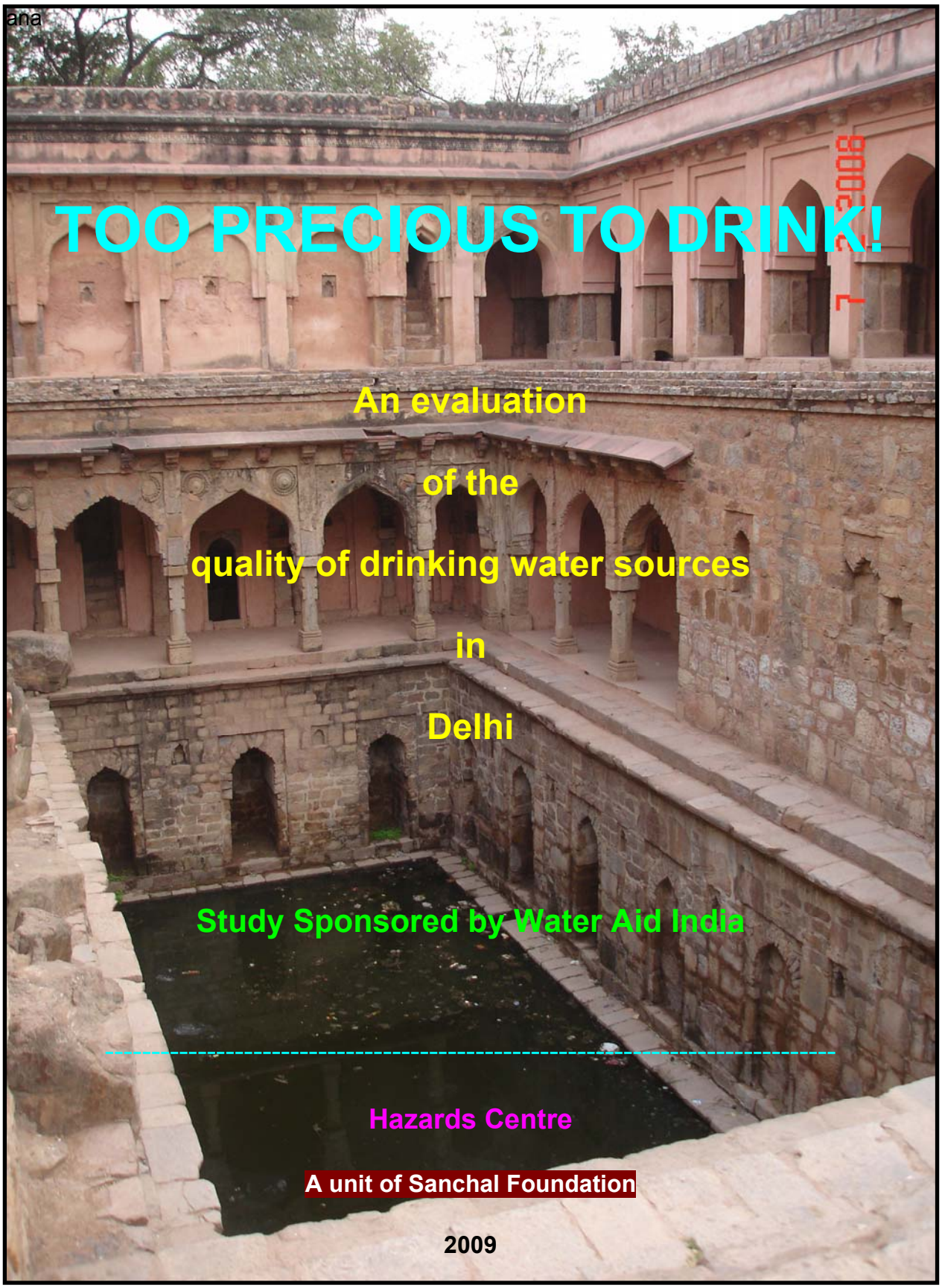

TOO PRECIOUS TO DRINK!

An evaluation

of the

quality of drinking water sources

in

Delhi

Study Sponsored by Water Aid India

Hazards Centre

A unit of Sanchal Foundation

2009

An evaluation of the quality of drinking water sources in Delhi

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Acknowledgements

This study would not have been possible without the generous support and encouragement of Water Aid India.

Hazards Centre would like to acknowledge the extensive support of Mansoor Khan, Raghuraj Singh, Prakash, Shivakant Gorakhpuri and Anila Shukla in mapping of water sampling sites and sample collection.

We appreciate the collaboration with the Environmental Quality Monitoring Group, People's Science Institute, Dehradoon and Prof. K. J. Mukherjee from Biotechnology Department, Jawaharlal Nehru University, New Delhi who provided the laboratory facility for analysing the samples. We are thankful to student intern Vivek Dogra for testing the samples and volunteer Nishtha Mehta for her inputs in preparing this report.

We also acknowledge Dr. Ashok Bhandari for his valuable assistance in designing the study.

Summary

Water that may be considered absolutely pure is not to be found in nature. Rainwater collects impurities such as dust, gases, and bacteria etc. during its passage through the atmosphere. When it flows as run-off and joins surface streams, it picks up organic and inorganic impurities; and as it percolates through the ground it gathers mineralogical, organic, and inorganic matter before reaching the water table. With increasing demand, water-intensive development and urbanization, water pollution from agricultural, domestic, municipal, and industrial sources has become a major concern for. Thus, the quality as well as the quantity of clean water supply is of vital significance for the welfare of human health and the environment.

Delhi mainly depends on the Yamuna River, canals from the upper reaches of the Yamuna and Ganga, and confined aquifers for its water sources. The city receives about 800 million gallons per day (mgd) of water. The chief source of surface water is the Yamuna, which supplies water to the northern, western, and central parts of Delhi. Eastern Delhi is mainly supplied by water from the Ganga canal; while ground water from bore wells is the main source for the southern part Delhi with a small amount extracted from Ranney wells in the bed of the Yamuna. The hydro-geological situation of alluvial formations and quartzitic hard rocks determines the availability of groundwater. Delhi Jal Board (DJB) is responsible for the purification of drinking water mainly from surface sources and the treated water reaches all parts of the city through a network of about 9,000km of mains and lines.

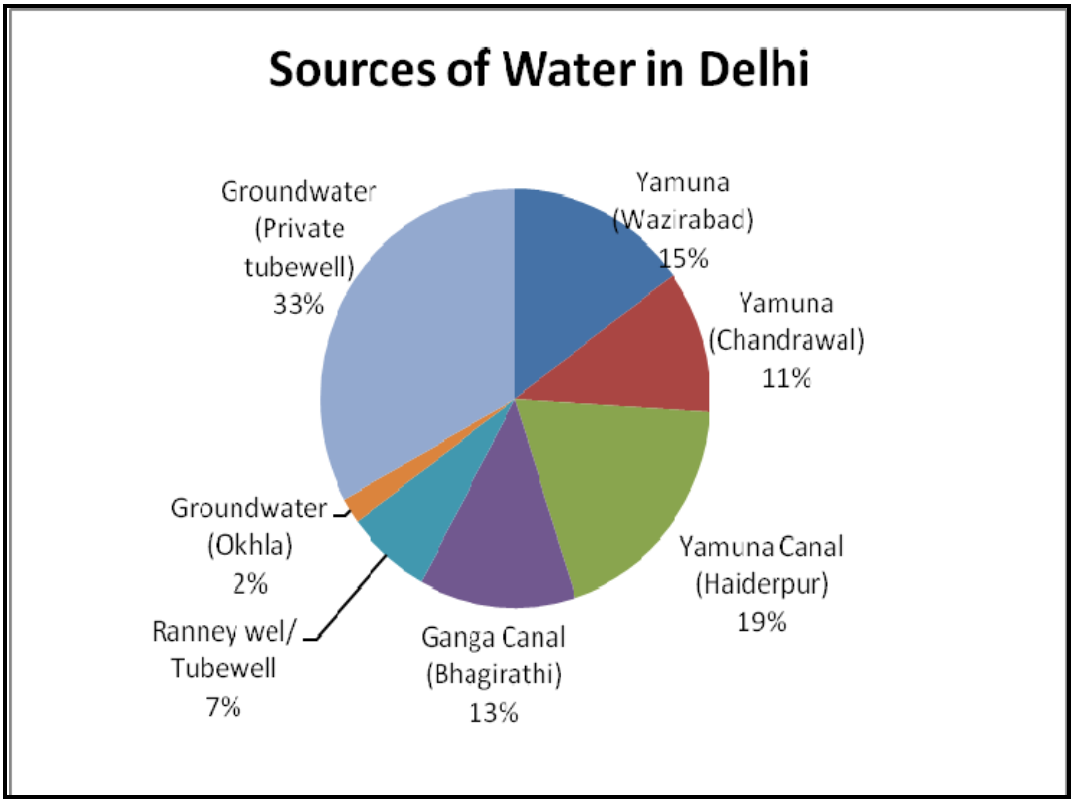
Hazards Centre with support from Water Aid has taken up this study in April to June 2009 to focus on the quality of water at the source, assess the efficiency of treatment carried out by DJB, as well as monitor the groundwater quality in zones which the Central Ground Water Board has designated as fresh water. The results are found out to be alarming as, out of a total of 53 samples collected from pipes, tankers, bore wells, and hand pumps, only 2 samples are potable i.e. free of both biological and chemical contamination. Even of the 7 samples collected from the nearest points of supply from water treatment plants, only 1 was found to be free of contamination.

Hopefully, this document will help to launch a debate on the accountability of those who are supposed to be the providers of clean and safe drinking water to the people of this *world class* city.

Introduction

Potable water is a basic human necessity and a necessary resource that should be managed and distributed wisely, equitably, and efficiently for the common good. However, there is increasingly uneven distribution of safe and adequate water, especially for marginalised social groups. As a result of this, the urban poor are often outside the purview of public policy. These exclusionary practices of water delivery have forced poorer residents of lower class settlements to access water for their basic survival using diverse means regardless of the quantity or quality of water available. The potability of this water is often unmonitored, making it a health hazard for the people being forced to rely on it. This health crisis is evident in the lives of the working poor in Delhi.

Delhi receives 800 million gallons per day (mgd) of water through a network of 9000km of pipes from the Yamuna, the Western Yamuna Canal, the Western Ganga Canal, and ground water where the chief water source is the Yamuna. 42% of the total supply is ground water supplied to the southern part Delhi from bore wells, while a small amount is extracted from Ranney wells located in the bed of the Yamuna.



Parameters of Water Safety:

The parameters for potable water specified by the Bureau of Indian Standards are given below:

S. N.	**Substance or Characteristic**	Requirement **Desirable Limit**	**Permissible Limit** in the absence of alternate source
	Essential characteristics		
1	Colour, (Hazen units) max	5	25
2	Odour	Unobjectionable	Unobjectionable
3	Taste	Agreeable	Agreeable
4	Turbidity (NTU) max	5	10
5	pH Value	6.5 to 8.5	No Relaxation
6	Total Hardness (as $CaCo_3$) mg/l, max	300	600
7	Iron (as Fe) mg/l, max	0.3	1.0
8	Chlorides (as Cl) mg/l, max	250	1000
9	Residual free chlorine, mg/l, min	0.2	--
	Desirable Characteristics		
10	Dissolved solids mg/l, max	500	2000
11	Calcium (as Ca) mg/l, max	75	200
12	Copper (as Cu) mg/l, max	0.05	1.5
13	Manganese (as Mn) mg/l, max	0.10	0.3
14	Sulfate (as SO_4) mg/l, max	200	400
15	Nitrate (as NO_3) mg/l, max	45	100
16	Fluoride (as F) mg/l, max	1	1.5
17	Phenolic Compounds (as C_6H_5OH) mg/l, max	0.001	0.002
18	Mercury (as Hg) mg/l, max	0.001	No relaxation
19	Cadmium (as Cd) mg/l, max	0.01	No relaxation
20	Selenium (as Se) mg/l, max	0.01	No relaxation
21	Arsenic (as As) mg/l, max	0.05	No relaxation
22	Cyanide (as CN) mg/l, max	0.05	No relaxation
23	Lea d (as Pb) mg/l, max	0.05	No relaxation
24	Zinc (as Zn) mg/l, max	5	15
25	Anionic detergents (as MBAS) mg/l, max	0.2	1.0
26	Chromium (as Cr^{6+})mg/l, max	0.05	No relaxation
27	Poly aromatic hydrocarbons (as PAH) g/l, max	--	--
28	Mineral Oil mg/l, max	0.01	0.03
29	Pesticides mg/l, max	Absent	0.001
30	Radioactive Materials		
	i. Alpha emitters Bq/l, max	--	0.1
	ii. Beta emitters pci/l, max	--	1.0
31	Alkalinity mg/l, max	200	600
32	Aluminium (as Al) mg/l, max	0.03	0.2
33	Boron mg/l, max	1	5

Coliform Count in any sample of 100ml is expected to be **zero** and Coliform organisms should **not be present** in 100 ml of any two consecutive samples.

Water quality monitoring

Monitoring and assessment of the quality of drinking water, by the supplier as well as the user, is very important for protecting health. Water quality is determined by assessing three classes of attributes: biological, chemical, and physical. There are standards of water quality set for each of these three classes. The *physical* impurities give taste, odour, colour and turbidity. The *chemical* parameters involve tests for determination of total solids, hardness, pH, chlorides, fluorides, dissolved solids, iron, manganese, other inorganics including heavy metals, and organic substances. *Biological* attributes comprise mainly of bacteriological tests for drinking water quality. Drinking water monitoring is done to check the potability of water. The nature of these chemical and biological parameters and their possible impacts on humans are given below.

pH is a measure of the acidic or basic (alkaline) nature of a solution. The concentration of the hydrogen ion [H^+] activity in a solution determines the pH. Mathematically this is expressed as: pH = - log [H^+]. pH determination is important for surface waters. Runoff from agricultural, domestic, and industrial areas may contain iron, ammonia, mercury or other elements. The pH of the water will determine the toxic effects, if any, of these substances. For example, 4ppm of iron would not present a toxic effect at a pH of 4.8. However, as little as 0.9ppm of iron at a pH of 5.5 can cause fish to die.

Electrical conductivity (EC) estimates the amount of total dissolved salts (TDS), or the total amount of dissolved ions in the water. EC is influenced by rock composition and size of the watershed. There may be other sources like waste water from treatment plants and urban runoff.

The presence of **Residual Chlorine** in drinking water indicates that: 1) a sufficient amount of chlorine was added initially to the water to deactivate the bacteria and some viruses that cause diarrhoeal disease; and 2) the water is protected from recontamination during storage. The presence of free residual chlorine in drinking water is correlated with the absence of disease-causing organisms, and thus is a measure of the potability of water. One should have optimum levels of chlorine in drinking water. Excess chlorine is harmful to the human body and less chlorine won't keep water safe for a long time. Hence, some excess chlorine is maintained in the water above the levels required for preliminary treatment.

Nitrate in water is derived from mineralization of soil organic matter or excessive use of nitrogen fertilizer and seepage of sewage. Babies below six months are susceptible to nitrate as it causes a disease named Blue Baby Syndrome (Methemoglobinaemia). In this syndrome 10% of haemoglobin in blood is converted into methanoglobin form. Death occurs when 40% of the haemoglobin is converted. It also causes goitre, gastrointestinal diseases, cardiovascular problems, vasodilatory problems in men, and also an increased rate of bearing malformed children in pregnant women. At high levels it causes cyanosis where haemoglobin becomes incapable of transporting oxygen. So it is very necessary that drinking water should be free of higher than desirable concentration of nitrates.

Fluoride largely occurs in chemical wastes from industries. Water drawn from the subsurface through some geological layers may also contain high amounts of fluorides. If it is present in small concentrations up to 1mg/l in water it causes reduction of teeth cavities in children. Children under nine years of age, if exposed to 2mg/l of fluoride, may develop a condition known as endemic dental fluorosis. In this condition there is dark brown spotting of the permanent teeth. In certain cases, the teeth become chalky white in appearance. Above 4mg/l it causes crippling skeletal fluorosis in humans, which is a serious bone disorder. Some other symptoms of fluorosis are: joint pains, gastro-intestinal discomfort, excessive thirst, excessive tendency to urinate, fatigue, muscle weakness, and frequent headache.

Chloride is a major constituent of most waters. It is normally present in low concentrations in surface water, while groundwater will contain varying amounts of chloride depending on the surrounding geology. The source of chloride is leaching of sedimentary rock and salt deposits, sewage and industrial discharge, leachates from dumps and landfills, and saltwater intrusion. Chloride is not harmful to people if it is not in high concentrations but it affects those who are suffering from heart and kidney disorders. Sudden increase in chloride may not have immediate effects but it indicates a connection with the source of contamination and will affect in the long run. It imparts a salty taste to drinking water. Chlorides also appear to exert a significant effect on the rate of corrosion of steel and aluminum and can therefore affect some metals used in water handling systems.

Total Iron is indicated by a red or orange tinge in water. The source of iron could be from natural sources such as soil and rocks or from corroded water pipes. Sometimes decaying vegetable matter also contains organic iron. Often the fine particles settle leaving clear water at the top. This is known as soluble, reduced, or "clear water iron". It is called "clear water iron" because the water out of the tap appears clear at first. After it settles and is exposed to the air, it becomes reddish-brown. Iron in the water may interfere with water treatment and may even support the growth of iron bacteria, iron algae. Iron bacteria produce a by-product Hydrogen Sulfide which, if the bacteria are plentiful, may impart a noticeable "rotten egg" smell to the water. Iron levels as low as 0.12mg/l may cloud the water and stain laundry and plumbing fixtures orange-brown. Though iron content in drinking water may not affect the human system as a simple dietary overload, but in the long run prolonged accumulation of iron in the body may result in haemochromatosis, where tissues are damaged. Iron may interfere with water treatment. During chlorination, iron combines with chlorine to form Ferric Chloride, which is not as effective as free chlorine in killing bacteria. Iron in levels above 5.0mg/l may make the water taste and smell so bad as to render it undrinkable without treatment.

Faecal Coliform, particularly E.Coli, Klebsiella, and Enterobacter, indicate that there are mammal or bird faeces in the water. The more mammals and birds are closely linked to our drinking water sources, the more likely it is that pathogens excreted along with their faeces can infect us. Human faeces are the biggest concern, because anything that infects one human could infect another. Ingesting faecal matter via contaminated water supply is a classic means for infections to spread rapidly. The more pathogens an individual carries, the more hazardous the faeces. Faecal Coliform bacteria flourish in the digestive tracts of humans. Some of these mutated organisms may cause diarrhoea, nausea, vomiting, and, in the very old, very young, and the immuno-suppressed, may even cause death. As a secondary infection Faecal Coliform causes urinary tract infection, gastro-intestinal diseases, septicemia etc. If any faecal bacteria are present in drinking water samples, it is said to be non-potable.

Arsenic is a chemical substance, which is released from the Earth's crust via natural processes and from certain human activities. It is introduced into water through the dissolution of minerals and ores, and concentrations in groundwater in some areas are elevated as a result of erosion from local rocks. The levels of arsenic in soil and sediment increase if there are natural and/or man-made sources of arsenic contamination present. Acute poisoning of arsenic typically includes vomiting, oesophageal and abdominal pain, and bloody "rice water" diarrhoea. Long-

term exposure to arsenic via drinking water causes cancer of the skin, lungs, urinary bladder, and kidney, as well as other skin changes in pigmentation and thickening (hyperkeratosis).

Lead is a soft, heavy, toxic, and malleable poor metal. It is bluish white when freshly cut but tarnishes to dull grey when exposed to air. The human body contains approximately 120mg of lead. About 10-20% of lead is absorbed by the intestines. Symptoms of overexposure to lead include intestinal pain, skin pigmentation, and paralysis. Generally, effects of lead poisoning are neurological or teratogenic[1]. Organic lead causes necrosis (death due to damage) of nerve cells[2]. Inorganic lead causes degeneration of nerve fibres. Both species of lead may cause cerebral oedema[3] and breathing problems. Organic lead compounds are absorbed quicker and, therefore, pose a greater risk. Organic lead derivatives may be carcinogenic (causing cancer). Women are generally more susceptible to lead poisoning than men. Lead causes menstrual disorders, infertility, and spontaneous abortion, and it increases the risk of stillbirth. Foetuses are more susceptible to lead poisoning than mothers, and foetuses may even protect mothers from lead poisoning. A long time ago lead was applied as a measure of birth control, for example as a spermicide[4], and to induce abortion. Children may absorb a larger amount of lead per unit body weight than adults (up to 40%). Consequently, children are generally more susceptible to lead poisoning than adults. Symptoms include lower IQ, behavioural changes and concentration disorders. Lead accumulates in leg tissues. The most severe type of lead poisoning causes encephalopathy or disease of the brain.

Chromium is a lustrous, brittle, hard metal. Its colour is silver-grey and it can be highly polished. Chromium is mined as chromite ($FeCr_2O_4$) ore. A total of 14 million tonnes of chromite ore is extracted every year. There are several different kinds of chromium that differ in their effects upon organisms. Chromium enters the air, water, and soil in the Cr^{3+} and Cr^{6+} forms through natural processes and man-made sources. It is a metal found in natural deposits as ores containing other elements. The greatest use of chromium is in metal alloys such as stainless steel; protective coatings on metal; magnetic tapes; and pigments for paints, cement, paper, rubber, composition floor covering and other materials. The health problems that are caused by chromium are skin rashes, upset stomachs and ulcers, respiratory problems,

[1] Disturbance of normal embryonic development
[2] Nerve cells or neurons are specialized cells of the nervous system which transmit signals to and from the brain and body; the movement and behaviour of the body depends on these signals
[3] Swelling due to excessive accumulation of fluid in tissue
[4] Substances that kills sperms

weakened immune systems, kidney and liver damage, alteration of genetic material, lung cancer, and death.

Cadmium is a naturally occurring minor element, one of the metallic components in the earth's crust and oceans, and present everywhere in our environment. Industrial applications for cadmium were developed in the late 19th and early 20th centuries. The effect of cadmium poisoning was first noticed in 1947, when a disease known as Itai Itai or Brittle Bone Disease was reported among the villagers living near the bank of Jintsu River in Japan. Cadmium causes several diseases in man like heart disease, high blood pressure, coronary-artery disease, respiratory diseases, loss of consciousness, abdominal cramps, nausea, vomiting, diarrhoea, bone disorder, rheumatism[5], weakness, kidney stones etc. If taken continuously or over a long period of time, Cadmium accumulates in the kidney and liver for a relatively long time, from 20 to 30 years, causing extensive damage to these organs. Cadmium has a long biological half-life, and it takes a long time for natural elimination from the body. At high doses, Cadmium is known to produce health effects on the respiratory system and has been associated with bone disease.

Pesticides are chemicals that are used to destroy insects, weeds, and pests around yards and gardens. There are three major families of pesticides: the chlorinated hydrocarbons or organochlorines, the organic phosphates or organophosphates, and the carbamates. The last family of pesticides is considered highly toxic to humans. Pesticides get into drinking water through surface water run-off from agricultural fields, golf courses, and residential properties into lakes, rivers, and reservoirs; rain and snow can carry pesticides by leaching through the soil into underground water supplies. Acute exposure causes diarrhoea, nausea, vomiting, abdominal pain, profuse salivation and sweating, blurred vision, skin and eye irritation, upper respiratory tract distress, oedema of the lungs, acute gastro-intestinal distress, headache, dizziness, drowsiness and seizure. Liver and lung cancer in humans as well as other types of cancer, genetic mutation, and foetal deformities have been associated with chronic exposure. The detection depends on the duration of exposure to the chemical, and how quickly the compound is metabolized and excreted from the body.

[5] A painful disorder of muscle and joints

Present Study

Hazards Centre has been working with several community groups and organisations in Delhi, many of them based in slums and resettlement colonies. The access to water for all these areas is poor in terms of both quality and quantity. There has been, in particular, great concern within these community groups about the quality of drinking water because it was affecting the health of entire populations. The demand from these groups was to check and monitor the quality of drinking water in these settlements. Hazards Centre worked with eleven slum clusters and resettlement colonies to assess the quality of drinking water in their residential areas in 2005-6. Water quality from different sources in these clusters was examined during pre-monsoon and monsoon seasons, and these results were then compared to study the seasonal variation in the status of drinking water. 90% of the samples were found to be unfit for drinking but it was not clear what the source of contamination was and, therefore, what remediation measures could be adopted. These unsatisfactory results led the Centre to take up another study in 2009, with generous support from Water Aid India, to focus on the quality of water at the source and assess the efficiency of the treatment plants.

Objectives:

The objectives of this study are:

- ***To evaluate the quality of raw water in surface and ground water sources***
- ***To monitor the actual functioning of the water treatment plants***
- ***To evaluate the quality of drinking water after treatment***
- ***To check the quality of drinking water sources during the pre- monsoon seaso***n

Methodology

This study began with a compilation of the information available from the websites of the Delhi Jal Board (DJB) and the Central Ground Water Board (CGWB) and Central Pollution Control Board (CPCB) with respect to the quality of water in Delhi. It should be noted that while the DJB site gives some information about the organisation, there is nothing available regarding either studies of the quality of water supplied by DJB nor about the pattern of distribution through different means such as pipelines, tankers, and hand pumps. Suitable areas for collection of samples were selected by overlaying maps of groundwater quality provided by CGWB and CPCB demarcating areas of fresh and brackish water along with the depths, and making sure that all categories were represented in the possible locations. From amongst these, settlements where the working poor live were chosen as sites since they are not equipped with any type of household water treatment facilities like Aquaguard, Reverse Osmosis etc. These sites were then visited to collect the preliminary information regarding the source of water, water availability, and timings, and actual sampling points chosen in collaboration and consultation with the communities. A workshop was conducted among selected individuals from the communities so that they could do their own water collection and preservation. Procedures of water sample collection were also taught along with methods for simple on-site measuring of parameters like Residual Chlorine, pH, and EC. So, in this study, collection and preservation of samples were done by community members with guidance from Hazards Centre researchers.

A total of 53 water samples were collected from surface water sources (3), piped water supply points nearest to water treatment plants (7), other piped water outlets (12), tankers (7), Ranney wells (6), hand pumps (7) and bore wells (11).

Sources of Water	Total samples	Sample nos.
Surface water sources	3	5, 33, 42
Piped water supply (nearest to WTPs)	7	4, 16, 17, 18, 26, 31, 48
Other piped water outlets	12	1, 2, 11, 13, 21, 27, 28, 30, 35, 36, 39, 41
Tankers	7	14, 22, 23, 25, 37, 38, 47
Ranney wells	6	34, 49, 50, 51, 52, 23
Hand pumps	7	3, 12, 15, 24, 29, 32, 40
Bore wells	11	6, 7, 8, 9, 10, 19, 20, 43, 44, 45, 46

The water quality check was based on two separate parameters – on-site and laboratory.

The following ***on-site parameters*** were monitored at the sampling point by the trained community members:

- pH
- EC
- Residual chlorine for the samples from treated supplies

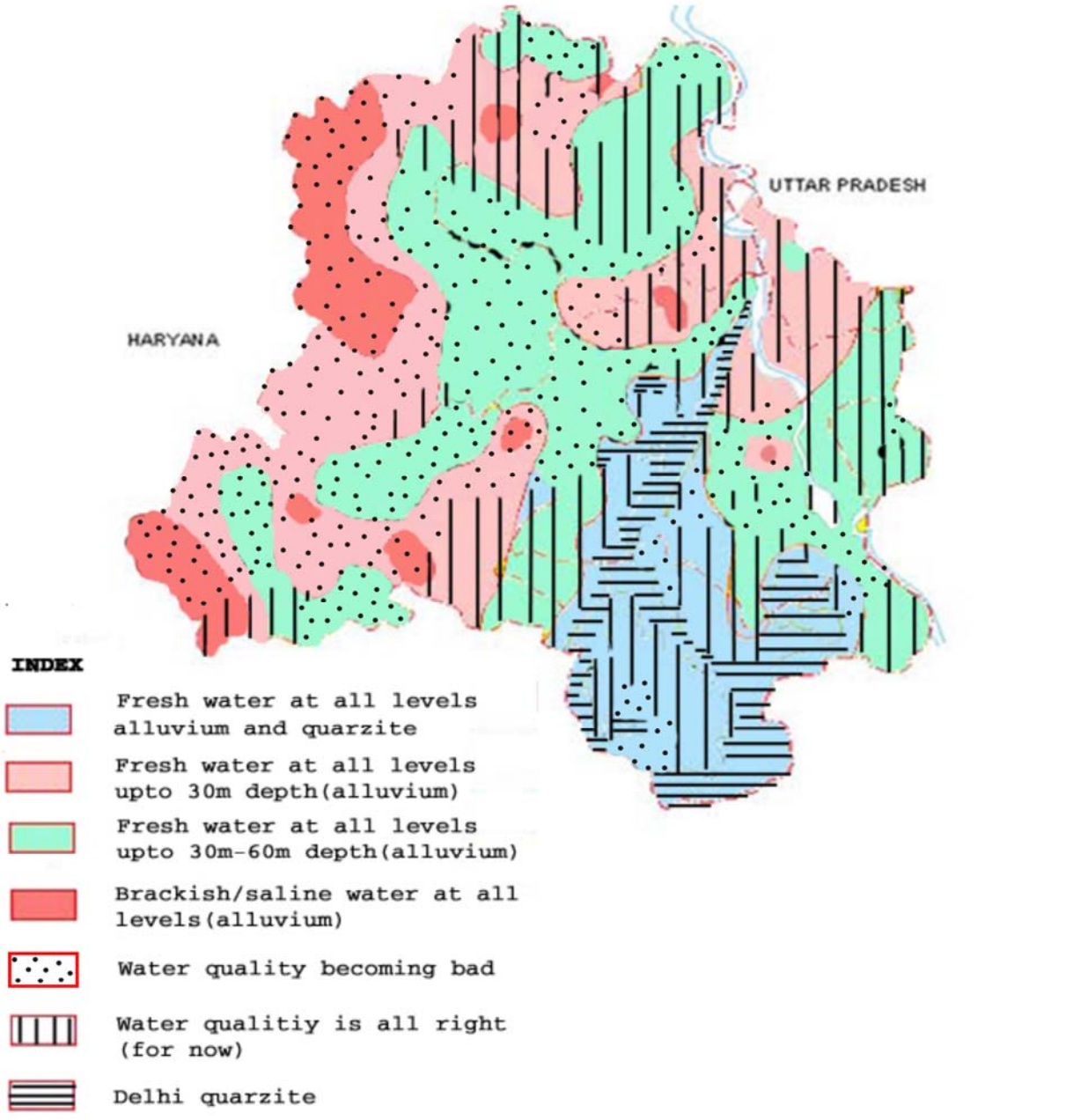
The following ***laboratory parameters*** were measured in the laboratory by Hazards Centre researchers and PSI staff (for heavy metals and pesticides):

- Total Dissolved Solids
- Chloride
- Fluoride
- Nitrate
- Phosphate
- Total Iron
- Heavy Metals (As, Cd, Cr, Pb)
- Pesticides (organochlorides & organophosphates)
- Faecal Coliform
- Bacterial Colony Count

The parameters like pH, EC, Residual Chlorine, Chloride, Fluoride, Nitrate, Total Iron and Faecal Coliform were tested by using a portable kit in which Fluoride is qualitatively measured through the colorimetric method and Faecal Coliform through the Most Probable Number (MPN) test which only indicates the presence or absence of Coliform in the sample. Bacterial Colony Count was done in the Biotechnology Department of Jawaharlal Nehru University, and the Heavy Metals and Pesticides were assayed in the laboratory of the Peoples Science Institute, Dehradun. All tests were performed in accordance with the standard methods published by APHA (American Public Health Association).

Location of Sites

The ground water map of Delhi prepared by the Central Ground Water Board, when overlaid with the water quality map of the Central Pollution Control Board (**Map 1.1**) indicates that the only area where fresh ground water is available at all levels and the water quality if acceptable is the Ridge area that intrudes into the alluvial plain, where much of the terrain is composed of fractured rock. To the east of the Ridge, in most of the alluvial basin adjacent to both sides of the Yamuna, the ground water is fresh at depths up to 60 metres but in many parts the quality is declining. Fresh ground water is similarly available in the alluvial plain to the west and north of the Ridge but only at depths ranging from 30 to 60 metres, while brackish water at all depths is present in pockets to the west. In addition, water quality is deteriorating in most of the western and northern plains. Hence, almost the entire western and central regions (with some exceptions in the south west) of the city are facing issues related to worsening water quality. The areas closer to the water treatment plants (Nangloi, Wazirabad, Chandrawal, Okhla), and certain regions in north, north-east and east of the city seem to have relatively better quality water at this time.

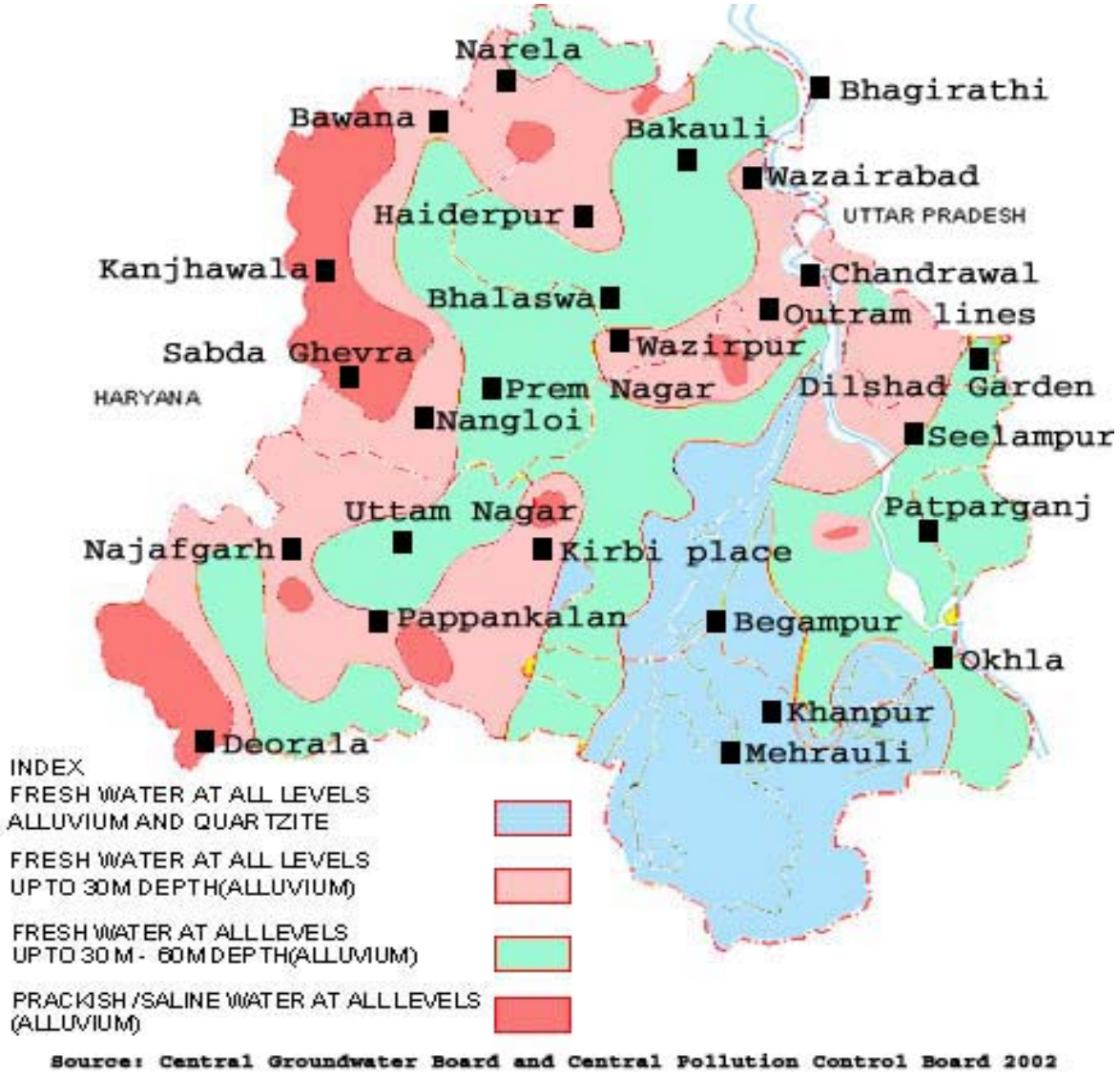


Source: Central Groundwater Board and Central Pollution Control Board 2002

Map 1.1: Water Quality in Delhi

For this study, an attempt was made to cover all the categories of ground water quality and its availability as well as the points from where surface water was being pumped out to supply water treatment plants. The sampling points are given in **Map 1.2**. Some points were also

chosen where water was being supplied by pipes from these treatment plants and care was taken to ensure that there was at least one point closest to the treatment plant. This became necessary since DJB would not give the research team permission to enter the plants and carry out an on-site examination of the effectiveness of the plants.



Map 1.2: Location of Drinking Water Samples

The composition of groundwater in a region depends on the natural (for example, soil type, rock type, deposition of atmospheric salts) and anthropogenic processes. These processes can affect the leaching of particular metals into groundwater. Alluvial regions cover approximately one-third of India's land area and aquifers formed by alluvium deposits are characterised by linear and shallow features making them vulnerable to pollution and other contamination. It is

found that groundwater in alluvium aquifers may have quantities of Iron, Lead, and Chromium above the permissible limit because of natural reasons, which can be further compounded by anthropogenic contamination.

Thus, a total of 53 water samples were collected from surface water sources (3), piped water supply points nearest to water treatment plants (7), other piped water outlets (12), tankers (7), Ranney wells (6), hand pumps (7), and bore wells (11) (details given in **Table 1**).

Results and Analysis

As mentioned earlier, Fluoride and Faecal Coliform were tested through qualitative methods which only provided information whether the sample contained these parameters above or below the permissible levels. Quantitative analysis was conducted by testing the water samples for pH, Electrical Conductivity, Residual Chlorine, Total Dissolved Solids, Chloride, Nitrate, Phosphate, Total Iron, Nitrate, Phosphate, Heavy Metals, Pesticides, and Bacterial Colony Count. Summary details of the results are given in **Table 1**.

The results reveals that the **pH** levels for all except two samples (out of 53) were within the Bureau of Indian Statistics' (BIS) prescribed range of 6.5-8.5. The **Total Dissolved Salts** (TDS) range from 91ppm to 1036ppm and only 7 samples were above the prescribed limit of 500ppm. **Residual Chlorine** was definitively absent from only 9 of the 26 DJB treated samples. The **Bacterial Colony Count** in the samples ranges from zero to 5000 colonies/ml. Yet 38 samples had **Faecal Coliform** and in 22 of them there was also high Bacterial Colony Count, even though in only 5 of these cases was Residual Chlorine *absent*, indicating that the degree of chlorination is grossly inadequate. In contrast, the **Nitrate** level in all samples was below or at the desirable limit providing some relief from high sewage infiltration and moreover **Phosphate** is within the prescribed limits.

In 11 of the samples the **Total Iron** was 3 mg/l, significantly above the desirable (0.3mg/l) and permissible (1mg/l) limits set by BIS. However, the results also indicate that 37 samples had above permissible levels of **Fluoride**, of which 15 were from piped water supplies and even from the river and a Ranney well while 20 were from ground water sources. This indicates that there may be significant contamination from both natural as well as anthropogenic causes.

The analysis also examined the presence of the **Heavy Metals** Arsenic (As), Lead (Pb), Cadmium (Cd), and Chromium (Cr) in the collected samples. The **Cr** in all collected samples was within the specified limits. However, there were 17 samples with **As** above the desirable limits, 8 samples with higher than desirable levels of **Pb**, and 8 samples with higher than desirable levels of **Cd**. Organo-chloro and Organo-phosphorous **Pesticides** were found in 20 and 10 samples respectively. These levels are of some concern, particularly when seen in the context of the high degree of Fluoride contamination of drinking water.

The summary analysis is presented in **Table 1** and detailed results of biological and chemical parameters are given in **Annexure 1**.

Table 1 – Summary Analysis of Water Quality

No.	Location	Source of Water	Observations	Potability
1	Indira Camp, Begumpur	DJB piped water supply	Residual chlorine ***absent*** Faecal Coliform is ***present***	**Non Potable**
2	Udham Singh Park, Wazirpur	DJB piped water supply	Fluoride is ***above*** permissible limit Total Iron is ***above*** permissible limit Arsenic is ***above*** desirable limit	**Non Potable**
3	Haiderpur Nirman Camp	Hand pump	Fluoride is ***above*** permissible limit Faecal Coliform ***present*** Organo-phosphorous Pesticides ***present***	**Non Potable**
4	Haiderpur Village	DJB piped water supply (Haiderpur WTP)	Fluoride is ***above*** permissible limit Lead is ***above*** desirable limit Organo-chloro Pesticides ***present***	**Non Potable**
5	Bawana	Yamuna Canal	Total Iron is ***above*** permissible limit Faecal Coliform is ***present***	**Non Potable**
6	Bawana JJC	Bore well supply (1km from the bore well)	Fluoride is ***above*** permissible limit Faecal Coliform ***present*** ***High*** bacterial colony count	**Non Potable**
7	Bawana JJC	Bore well (from points near the bore well)	Fluoride is ***above*** permissible limit Total Iron is ***above*** permissible limit Faecal Coliform ***present*** ***High*** bacterial colony count	**Non Potable**
8	Bawana JJC (F-block)	Submersible pump	Fluoride is ***above*** permissible limit. Faecal Coliform is ***present*** ***High*** bacterial colony count Organo-chloro Pesticides ***present***	**Non Potable**
9	Swarna Jayanti Vihar JJC, Tikri Khurd, Narela	Bore well (nearest point)	Fluoride is ***above*** permissible limit Faecal Coliform is ***present***	**Non Potable**
10	Swarna Jayanti Vihar JJC, Tikri Khurd, Narela	Bore well (1km distance)	Fluoride is ***above*** permissible limit Faecal Coliform is ***present*** Lead is ***above*** desirable limit	**Non Potable**
11	Bakauli Village	DJB piped water supply	Faecal Coliform is ***present*** ***High*** bacterial colony count	**Non Potable**
12	Bakauli village	Hand Pump	Arsenic is ***above*** desirable limit Organo-chloro Pesticides ***present***	**Non Potable**

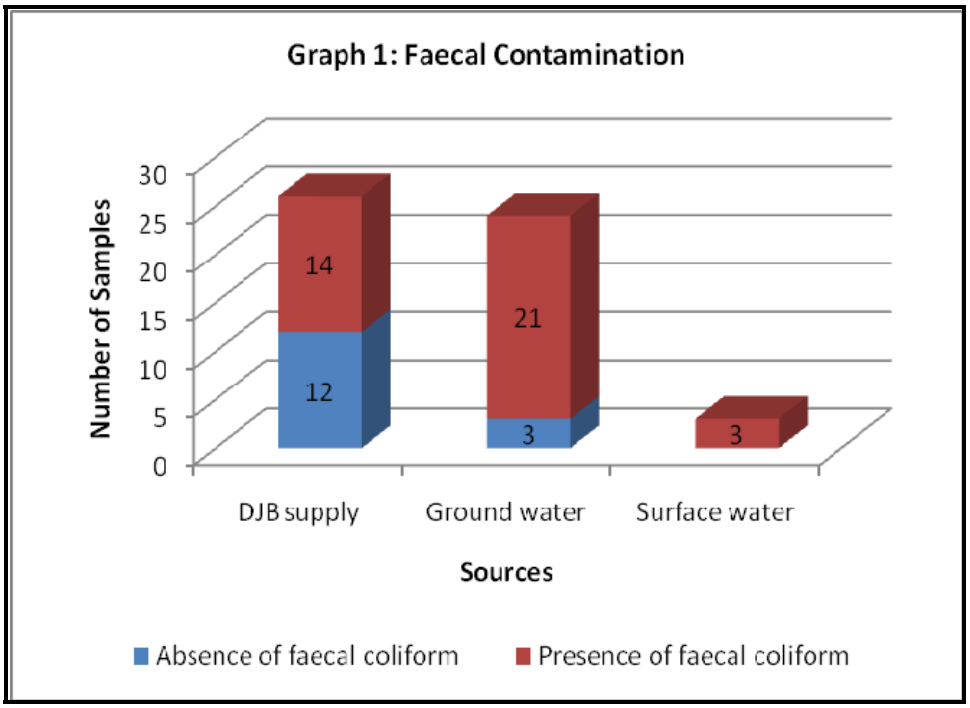
13	Bhalaswa JJC	DJB piped water supply	Fluoride is ***above*** permissible limit Residual chlorine ***absent*** ***High*** bacterial colony count Lead is ***above*** desirable limit Organo-phosphorous Pesticides ***present***	**Non Potable**
14	Bhalaswa JJC	Tanker water	Fluoride is ***above*** permissible limit Residual chlorine ***absent*** Faecal Coliform is ***present*** ***High*** bacterial colony count	**Non Potable**
15	Bhalaswa JJC	Hand pump	Fluoride is ***above*** permissible limit. Faecal Coliform is ***present*** ***High*** bacterial colony count Arsenic is ***above*** desirable limit Organo-choloro and phosphorous Pesticides ***present***	**Non Potable**
16	Chandrawal Treatment Plant 2	DJB piped water supply	***High*** bacterial colony count Arsenic is ***above*** desirable limit	**Non Potable**
17	Chandrawal Treatment Plant 1	DJB piped water supply	***High*** bacterial colony count	**Non Potable**
18	Outram Lines (JJC), Camp	DJB piped water supply	Faecal Coliform is ***present*** ***High*** bacterial colony count Arsenic is ***above*** desirable limit Organo-chloro Pesticides ***present***	**Non Potable**
19	Nirman Camp, Haiderpur	Bore well (nearest point)	Fluoride is ***above*** permissible limit Faecal Coliform is ***present*** ***High*** bacterial colony count Organo-chloro Pesticides ***present***	**Non Potable**
20	Nirman Camp, Haiderpur	Bore well (1km distance)	Fluoride is ***above*** permissible limit Faecal Coliform is ***present*** ***High*** bacterial colony count Arsenic is ***above*** desirable limit	**Non Potable**
21	Mahavir Vihar, Kanjhawala	DJB piped water supply	Fluoride is ***above*** permissible limit Arsenic is ***above*** desirable limit	**Non Potable**
22	Mahavir Vihar, Kanjhawala	Tanker water	--	**Potable Water**
23	Sabda Ghewra JJC	Tanker water	Faecal Coliform is ***present***	**Non Potable**

24	Prem Nagar – III	Hand pump	Faecal Coliform is ***present*** ***High*** bacterial colony count Arsenic is ***above*** desirable limit Organo-phosphorous Pesticides ***present***	**Non Potable**
25	Prem Nagar – II	Tanker water	Arsenic is ***above*** desirable limit Organo-chloro Pesticides ***present***	**Non Potable**
26	Nangloi Treatment Plant	DJB piped water supply	Faecal Coliform is ***present*** Arsenic is ***above*** desirable limit Organo-chloro Pesticides ***present***	**Non Potable**
27	New Seelampur	DJB piped water supply	Faecal Coliform is ***present*** Organo-chloro and phosphorous Pesticides ***present***	**Non Potable**
28	Kalander Colony, Dilshad Garden	DJB piped water supply	Fluoride is ***above*** permissible limit Faecal Coliform is ***present***	**Non Potable**
29	Kalander Colony, Dilshad Garden	Hand pump	Fluoride is ***above*** permissible limit Total Iron is ***above*** permissible limit Faecal Coliform is ***present*** ***High*** bacterial colony count Lead is ***above*** the desirable limit Organo-chloro Pesticides ***present***	**Non Potable**
30	Rajiv Camp 1, Patparganj	DJB piped water supply	Fluoride is ***above*** permissible limit Faecal Coliform is ***present*** ***High*** bacterial colony count Arsenic is ***above*** desirable limit	**Non Potable**
31	Gokulpuri (near Bhagirathi)	DJB piped water supply	--	**Potable Water**
32	Sonia Vihar, Pushta -1	Hand pump	Faecal Coliform is ***present*** ***High*** bacterial colony count Arsenic is ***above*** desirable limit	**Non Potable**
33	Yamuna River	Surface Water	pH is ***above*** permissible limit Fluoride is ***above*** permissible limit Faecal Coliform is ***present*** Arsenic is ***above*** desirable limit	**Non Potable**
34	Nanaksar	Ranney well	pH is ***above*** permissible limit Fluoride is ***above*** permissible limit Faecal Coliform is ***present*** Lead is ***above*** desirable limit Organo-chloro and phosphorous Pesticides ***present***	**Non Potable**
35	Pappankala JJC	DJB piped water supply	Fluoride is ***above*** permissible limit Residual chlorine ***absent*** Faecal Coliform is ***present*** ***High*** bacterial colony count Lead is ***above*** desirable limit	**Non Potable**

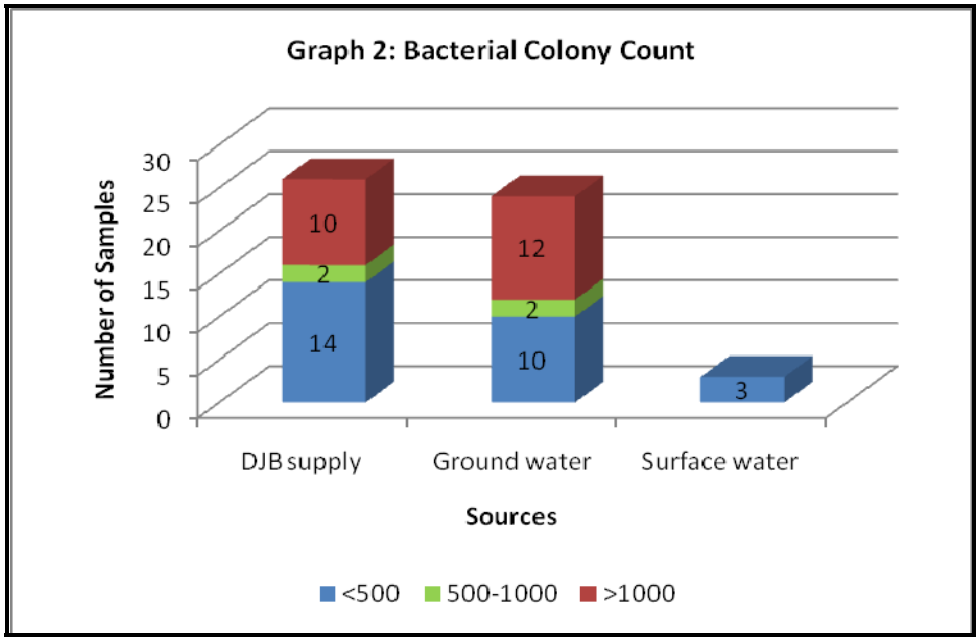
36	Pankha road, Uttam Nagar	DJB piped water supply	Fluoride is ***above*** permissible limit Total Iron is ***above*** permissible limit Residual chlorine ***absent*** Faecal Coliform is ***present*** ***High*** bacterial colony count Cadmium is ***above*** desirable limit. Arsenic is ***above*** desirable limit	**Non Potable**
37	Najafgarh	Tanker water	Fluoride is ***above*** permissible limit Total Iron is ***above*** permissible limit Lead is ***above*** desirable limit Organo-chloro and phosphorous Pesticides ***present***	**Non Potable**
38	Deorala village	Tanker water	Fluoride is ***above*** permissible limit Residual chlorine ***absent*** Faecal Coliform is ***present*** Organo-chloro Pesticides ***present***	**Non Potable**
39	Naya Bazar, Najafgarh	DJB piped water supply	Fluoride is above permissible limit	**Non Potable**
40	Kirbi Place, Dhobi Ghat	Hand pump	Fluoride is ***above*** permissible limit Faecal Coliform is ***present*** ***High*** bacterial colony count Arsenic is ***above*** desirable limit Organo-chloro and phosphorous Pesticides ***present***	**Non Potable**
41	Kirbi Place, Dhobi Ghat	DJB piped water supply	Fluoride is ***above*** permissible limit Residual chlorine ***absent*** Lead is ***above*** desirable limit Arsenic is ***above*** desirable limit	**Non Potable**
42	Murad Nagar	Canal	Faecal Coliform is ***present*** Cadmium is ***above*** desirable limit	**Non Potable**
43	Khanpur JJC	Bore well (nearest point)	Fluoride is ***above*** permissible limit Faecal Coliform is ***present*** ***High*** bacterial colony count Arsenic is ***above*** desirable limit Organo-chloro Pesticides ***present***	**Non Potable**
44	Khanpur JJC	Bore well (1 km distance)	Fluoride is ***above*** permissible limit Faecal Coliform is ***present*** Cadmium is ***above*** desirable limit Organo-chloro Pesticides ***present***	**Non Potable**
45	Nat colony, Chattarpur, Mehraulli	Bore well (nearest point)	Fluoride is ***above*** permissible limit Faecal Coliform is ***present***	**Non Potable**

46	Nat colony, Chattarpur, Mehraulli	Bore well (1 km distance)	Fluoride is ***above*** permissible limit Faecal Coliform is ***present*** ***High*** bacterial colony count Cadmium is ***above*** desirable limit Organo-chloro Pesticides ***present***	**Non Potable**
47	Nat colony, Chattarpur, Mehraulli	Tanker water	Fluoride is ***above*** permissible limit Residual chlorine ***absent*** Faecal Coliform is ***present*** ***High*** bacterial colony count Organo-chloro and phosphorous Pesticides ***present***	**Non Potable**
48	Okhla treatment plant	DJB piped water supply	Fluoride is ***above*** permissible limit Total Iron is ***above*** permissible limit Faecal Coliform is ***present*** Cadmium is ***above*** desirable limit	**Non Potable**
49	Vikas Marg	Ranney well No.7	Fluoride is ***above*** permissible limit Total Iron is ***above*** permissible limit Cadmium is ***above*** desirable limit Organo-phosphorous Pesticides ***present***	**Non Potable**
50	Akshar Dham	Ranney well No.5	Fluoride is ***above*** permissible limit Total Iron is ***above*** permissible limit Faecal Coliform is ***present***	**Non Potable**
51	Vikas Marg	Ranney well No.8	Fluoride is ***above*** permissible limit Faecal Coliform is ***present*** Organo-chloro Pesticides ***present***	**Non Potable**
52	Yamuna	Ranney well No.3	Fluoride is ***above*** permissible limit Total Iron is ***above*** permissible limit Cadmium is ***above*** desirable limit Organo-chloro Pesticides ***present***	**Non Potable**
53	CWG village	Ranney well No.3	Fluoride is ***above*** permissible limit Total Iron is ***above*** permissible limit Faecal Coliform is ***present*** Cadmium is ***above*** desirable limit	**Non Potable**

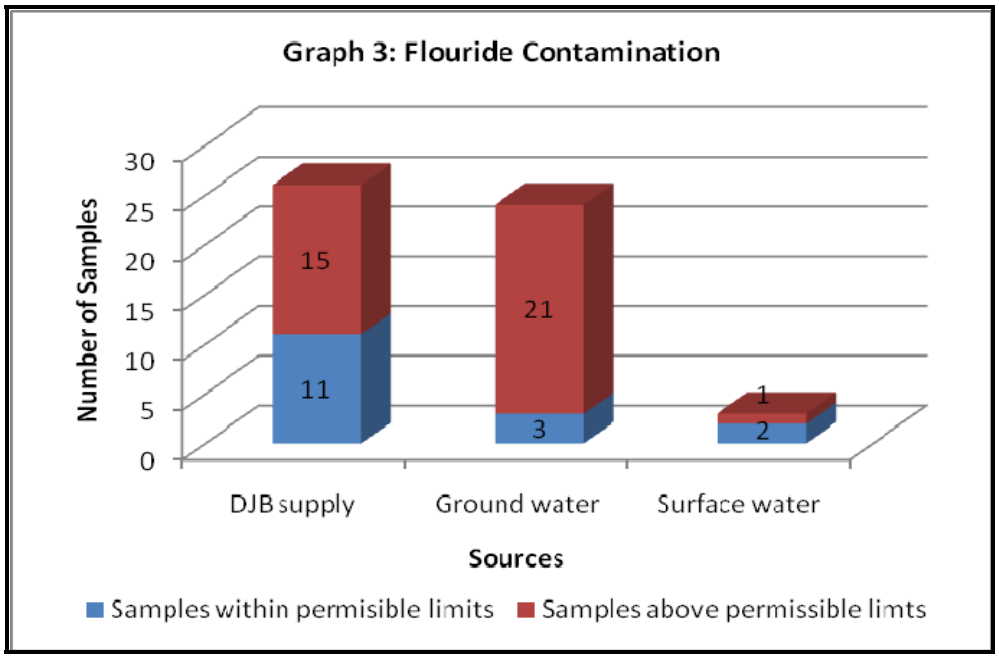
When certain quality parameters are above the permissible limits, the water is rendered non-potable and becomes a health hazard for the users. ***This study reveals that only 2 of the 53 drinking water samples were potable where one sample was from the outlet nearest to the Bhagirathi Water Treatment Plant and the other sample was from a tanker which supplies water to Mahavir Vihar, Kanjhawala on the outskirts of rural Delhi***. 72% of the total water samples were faecally contaminated; out of which 27% were samples where water is supplied by DJB, 39% are ground water samples **(Table 2)**, and 6% are surface water samples (**Graph 1**).



This shows that not only are surface and ground water contaminated but DJB supplies are also not free from contamination. In case of bacterial colony counts, 1000-5000 colonies/ml are found in 40% of the total samples; out of which 18% are from water supplied by DJB and 22% from ground water sources **(Graph 2).**



In the case of Fluoride contamination **(Graph 3)**, 72% of the total water samples contain fluoride above the permissible limit; out of which 29% water is supplied by DJB, 41% is ground water **(Table 2)** and 2% is surface water where excess of fluoride can cause several skeletal and blood disorders.



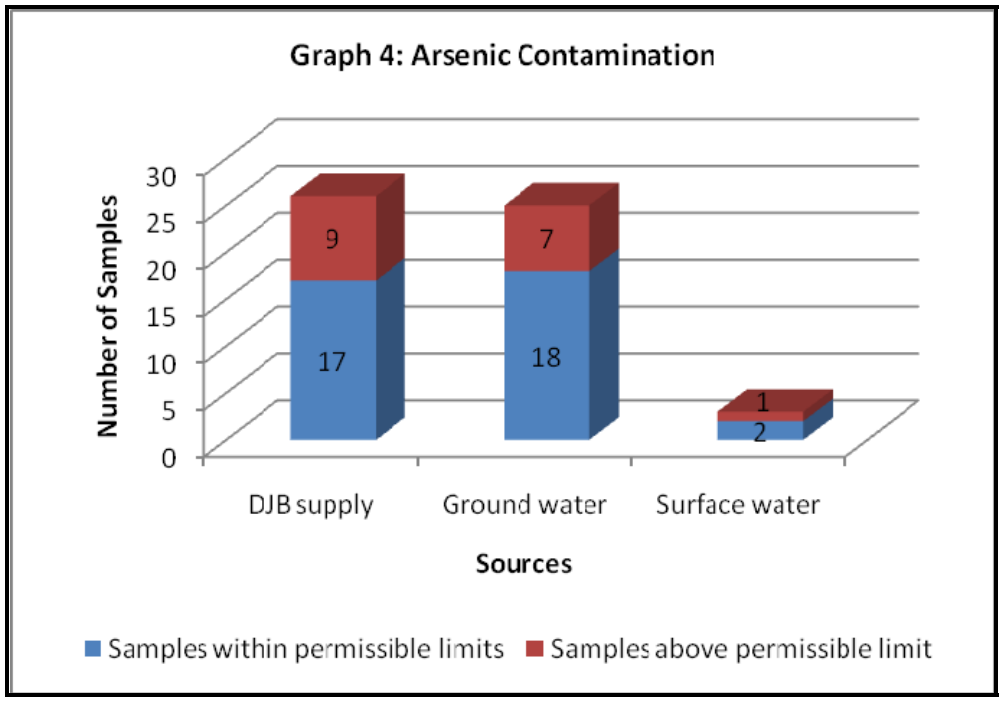


Table 2 - Groundwater quality with relation to the depth given by CGWB

CGWB depth	Test location	GW source	Test parameters		
			Faecal Coliform	Fluoride	Arsenic
Fresh water at all levels	Bawana JJ colony	Bore well supply (1km distance)	Present	APL	WPL
	Bawana JJ colony	Bore well (nearest point)	Present	APL	WPL
	Swarna Jayanti Vihar JJC, Narela	Bore well (nearest point)	Present	APL	WPL
	Swarna Jayanti Vihar JJC, Narela	Bore well (1km distance)	Present	APL	WPL
	Khanpur JJ Colony	Bore well (nearest point)	Present	APL	APL
	Khanpur JJ colony	Bore well (1 km distance)	Present	APL	WPL
	Nanak sar	Ranney well	Present	APL	WPL
Fresh water at all levels upto 30m depth	Nirman Camp, Haiderpur	Bore well (nearest point)	Present	APL	WPL
	Nirman Camp, Haiderpur	Bore well (1km distance)	Present	APL	WPL
	Nat colony, Mehraulli	Bore well (nearest point)	Present	APL	WPL
	Nat colony, Mehraulli	Bore well (1 km distance)	Present	APL	WPL
	Vikas Marg	Ranney well No.7	Absent	APL	WPL
	Akshar Dham	Ranney well No.5	Present	APL	WPL
	Vikas Marg	Ranney well No.8	Present	APL	WPL
	Yamuna	Ranney well No.3	Present	APL	WPL
	CWG village	Ranney well No.4	Absent	APL	WPL
Fresh water at all levels upto 30-60m depth	Bawana JJ colony (F-block)	Submersible pump in tube well	Present	APL	WPL
	Haiderpur Nirman Camp	Hand pump	Present	APL	WPL
	Bakauli village	Hand pump	Absent	WPL	APL
	Bhalaswa JJ Colony	Hand pump	Present	APL	APL
	Prem Nagar – III	Hand pump	Present	WPL	APL
	Kalander Colony, Dilshad Garden	Hand pump	Present	APL	WPL
	Sonia Vihar	Hand pump	Present	WPL	APL
	Kirbi Place, Dhobi Ghat	Hand pump	Present	APL	APL

WPL = within permissible levels; APL = above permissible levels

Arsenic is also found in 30% of the water samples of which 17% is from DJB supplied water, 11% from ground water **(Table 2)**, and 2% from surface water sources **(Graph 4).** The presence of Fluoride and Arsenic, particularly in DJB piped water supply, is a matter of concern as both have serious long term effects on human health. The source of these elements in both surface and ground waters needs to be further investigated to establish whether it is of natural or human origin and what should be the appropriate remedial measures.

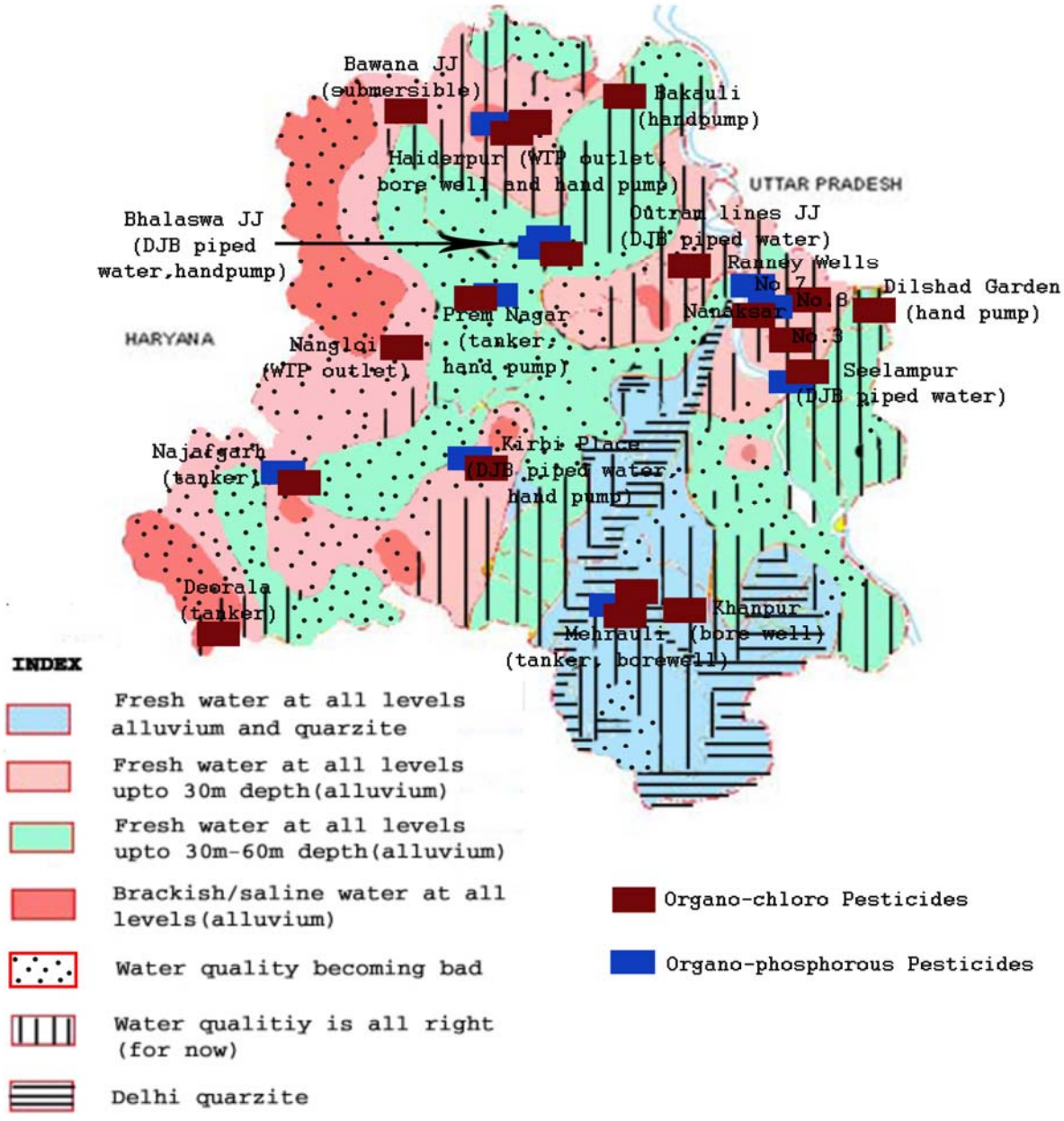
There are also a significant number of samples with non-desirable levels of Total Iron (19%), Lead (17%) and Cadmium (13%). Exposure to an excess of these metals can result in diseases related to the kidneys, stomach, and reproductive organs. Along with other contaminants, Pesticides are also found at various sampling sites **(Map 2)** in the form of Organo-chloro and Organo-phosphorous Pesticides. These pesticides are found mostly in ground water samples but the piped water and tankers are also not totally free of contamination. Details are given in **Annexure 2**.

Different types of organo-chloro pesticides are found in 20 of the total 53 samples tested. The presence of **δ BHC** in 5 out of 20 samples and **Hepatochlor-epoxide**, **44 DDD**, and **44 DDE** in 4 samples each (**Annexure 2**) apart from the presence of **α BHC**, **γ BHC**, **Endo sulphate**, **Endrin aldehyde**, **Dieldrin**, **Aldrin**, and **Endrin** in 1 or 2 samples is disturbing and merits further attention as it indicates that run-off from agricultural fields as well as sewage from domestic and industrial units may be leaching into the ground. These pesticides are of particular significance as they are persistent and have long-term effects on the consuming population, and many of them have been banned under the law.

Similarly out of total 53 water samples, 10 show the presence of different organo-phosphorous pesticides, such as **Chloropyrifos**, **Cypermethrine**, and **Monocrotophos**. This further adds to the concern as these pesticides have recently replaced the organo-chloro pesticides as being relatively less toxic, but their ingress into ground water sources that feed the water supply scheme through DJB piped water and Ranney wells is not a happy augury, particularly since there is no treatment in place for these pesticides.

What is also of note is that these pesticides are found distributed mainly in the alluvial aquifers where fresh water is supposed to be available at depths up to 30m, although a few are sweet up to deeper depths, and they would be feeding a number of shallow hand pumps which are the basic source of water for poorer – and less well-provided – communities. Therefore, they would

also be adversely impacting a population even less equipped to deal with such long term impacts.



Source: Central Groundwater Board and Central Pollution Control Board 2002

Map 2: Pesticide Contamination in Sampling Sites

All **surface water** in the study area is also contaminated. The level of chemicals, metals, and biological contaminants was found to be extremely high in surface water sources. This indicates that there is little or no access to potable water in the city unless people have the means to purchase treated water from outside sources. This study, when seen in combination with the previous 2005-2006 study conducted by the Hazards Centre, indicates that the inequitable distribution of drinking water in the city shifts the burden of the effects produced by low quality water disproportionately to the urban poor in the city (Hazards Centre, 2007).

The performance of Delhi Jal Board

These results prove that the supply of drinking water in the lower class settlements of Delhi is highly contaminated biologically and in all likelihood would be the cause of the prevalent water-borne diseases like typhoid, dysentery, gastroenteritis, and hepatitis-A. The contamination is not merely from ground water sources that may be polluted because of seepage and leakages from waste disposal systems, but is also present in piped water supplies provided by DJB – which would otherwise be expected to be adequately treated so that there is no contamination at the user's end. However, contrary to expectations, it is seen that 38% of the water samples (10/26) supplied by DJB through pipes and tankers are devoid of residual chlorine. It is also observed that the water samples taken from the taps (sample no. 4, 31, 17, 16, 18, 26 and 48) nearest to the water treatment plants show the presence of residual chlorine in these 7 samples and yet in sample 18, 26 and 48 there is the presence of faecal contamination. Thus, the responsibility of DJB to provide uncontaminated water has clearly not been fulfilled.

In spite of several sustained attempts the Hazards Centre team was unable to obtain permission from the Delhi Jal Board to visit any of their water treatment plants. Hence, it was not possible to determine what treatment process was being followed in these plants and how effective this treatment was. Consequently, the team then took inlet and outlet samples from as near the plants as possible to assess the probable effectiveness of the water treatment process. The results showed that the inlet water into all the water treatment plants was non-potable, while the outlet quality at only two locations (Chandrawal-2 and Gokulpuri near Bhagirathi)) could be considered to be potable (**Table 2**), although in the case of the former the bacterial colony count is still very high.

Table 3: Inlet-Outlet Water Quality of Water Treatment Plants

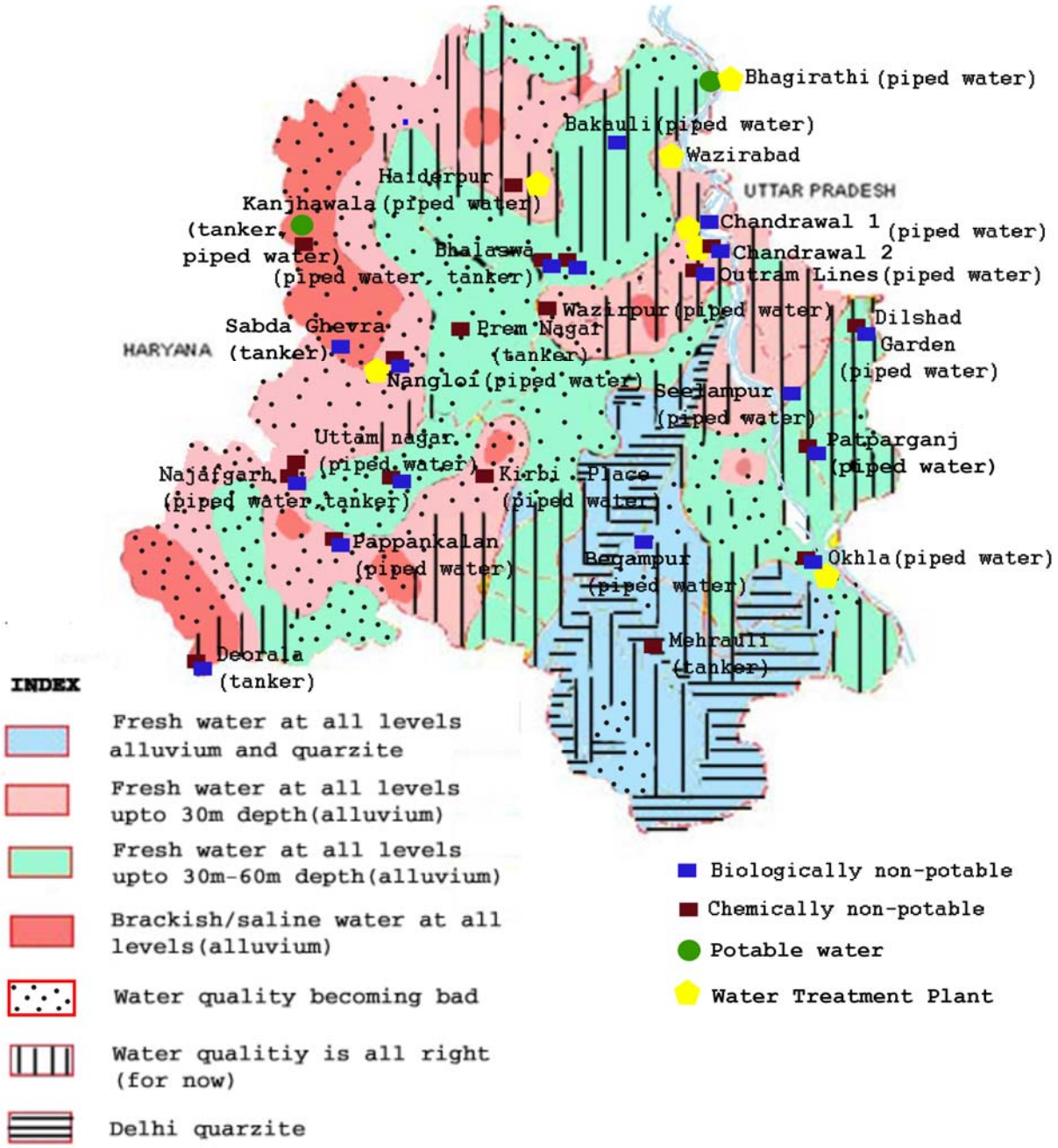
Treatment Plant (inlet and nearest outlet)		No.	Location	Chemical Analysis									Bacteriological Analysis		Heavy Metals (mg/l)			
				pH	EC (□mho-cm)	TDS (mg/l)	Residual chlorine (mg/l)	Chloride (mg/l)	Fluoride	Nitrate (mg/l)	Phosphate (mg/l)	Total Iron (mg/l)	Faecal Coliform	Bacterial Colony Count (colonies/ml)	Pb	Cd	As	Cr
Haiderpur	*Inlet*	5	*Yamuna Canal (Bawana)*	*8.3*	*137*	*95.9*	-	*48*	*WPL*	*1*	*0.1*	3	*Present*	*46*	*BDL*	*0.002*	*BDL*	*ND*
	Outlet	4	Haiderpur Village	7.9	135	94.5	2	36	APL	3	0.1	0	Absent	60	0.288	BDL	0.02	0.002
Bhagirathi	*Inlet*	*42*	*Murad Nagar Canal*	*8.7*	*226*	*158*	--	*44*	*WPL*	*1*	*0.1*	*0.1*	*Present*	*158*	*0.01*	*0.02*	*BDL*	*0.012*
	Outlet	31	Gokulpuri (near Bhagirathi)	8	92	64.4	2	40	WPL	1	0	0.1	Absent	None	BDL	0.002	BDL	ND
Chandrawal	*Inlet*	*42*	*Murad Nagar Canal*	*8.7*	*226*	*158*	--	*44*	*WPL*	*1*	*0.1*	*0.1*	*Present*	*158*	*0.01*	*0.02*	*BDL*	*0.012*
	Outlet	17	Chandrawal Treatment Plant 1	7.8	194	136	4	68	WPL	1	0.1	0	Absent	2400	0.025	0.004	0.041	0.009
		16	Chandrawal Treatment Plant 2	8.1	201	141	4	92	WPL	1	0.1	0.7	Absent	2200	0.006	0.003	0.074	ND
Wazirabad	*Inlet*	33	*Yamuna River*	*9*	*172*	*120*	--	*160*	*APL*	*0*	*0*	*0*	*Present*	*83*	*BDL*	*0.004*	*0.08*	*ND*
	Outlet	18	Outram Lines, DU	7.9	188	132	2	100	WPL	0	0	0.1	Present	1500, fungi	BDL	BDL	0.067	0.003

Nangloi	*Inlet*	5	*Yamuna Canal (Bawana)*	*8*	*137*	*95.9*	-	*48*	*WPL*	*1*	*0.1*	*3*	*Present*	*46*	*BDL*	*0.002*	*BDL*	*ND*
	Outlet	26	Nangloi Treatment Plant	7.2	138	97	.5	48	WPL	0	0.1	0	Present	40	BDL	0.004	0.06	ND
Okhla	*Inlets*	*34*	*Nanaksar Ranney well*	*9.3*	*172*	*120*	--	*64*	*APL*	*1*	*0*	*0.1*	*Present*	*53*	*0.239*	*BDL*	*0.019*	*ND*
		49	*Ranney well No.7*	*8.1*	*405*	*380*	--	*48*	*APL*	*10*	*0.1*	*>3*	*Absent*	*20*	*0.006*	*0.017*	*BDL*	*ND*
		50	*Ranney well No.5 (near Akshar Dham)*	*7.8*	*631*	*477*	--	*188*	*APL*	*0*	*0.1*	*>3*	*Present*	*60*	*0.005*	*ND*	*BDL*	*ND*
		51	*Ranney well No.8 (near Vikas Marg)*	*8.1*	*477*	*1036*	--	*28*	*APL*	*0*	*0.1*	*0.1*	*Present*	*500*	*ND*	*ND*	*BDL*	*ND*
		52	*Ranney well No.3 (near Yamuna)*	*7.6*	*1036*	*405*	--	*40*	*APL*	*10*	*0.1*	*>3*	*Absent*	*15*	*ND*	*0.02*	*BDL*	*0.007*
		53	*Ranney well No.4 (CWG village)*	*7.9*	*380*	*631*	--	*240*	*APL*	*45*	*0.1*	*3*	*Present*	*50*	*0.003*	*0.047*	*BDL*	*0.008*
	Outlet	48	Okhla Treatment Plant	7.9	92	64.6	1	68	APL	1	0	>3	Present	None	0.011	0.042	BDL	0.01

WPL = within permissible levels; APL = above permissible levels; BDL = below detectable levels; ND = not detected

The role of Delhi Jal Board for supplying safe drinking water to the city can be summed up through the above Table 2. Raw water, i.e. the surface water which comes to the water treatment plants for treatment, is taken as the *inlet* condition; and the *outlet* is the nearest tap on the main line coming out of the treatment plant which finally joins a network of lines that is distributed to the city. Tests of the water samples from inlet (raw water) and outlet (treated water) of the 7 treatment plants (**Table 3**) depict that all *inlet* samples (except for the Ranney wells no.7 and no.3) are **faecally** contaminated. When this water gets treated in the 7 plants for the removal of bacterial contamination, the 3 treatment plants at Wazirabad, Nangloi, and Okhla are unable to remove the **Faecal Coliform**, while two other plants at Chandrawal contribute a high **bacterial colony count** above 2000 colonies/ml. Only the plants at Haiderpur and Bhagirathi may be said to treat the water adequately for micro-biological pollutants. Only in Chandrawal 1 does the outlet contain **residual chlorine** up to 4mg/l. In other words, the functioning of most of the DJB water treatment plants is deficient for public health.

In addition, none of the plants seem to have any specific measures to deal with heavy metal contamination. The chemical analysis reveals that **Fluoride** and **Lead** are found in quantities above the permissible levels in the outlet sample of Haiderpur treatment plant whereas the inlet sample shows these within permissible limits. All the Ranney well samples, i.e. the inlets for Okhla WTP, show high **Fluoride** content which may be because of pollution in the source in the Yamuna, but the outlet of Okhla WTP also has a high fluoride content as there is no provision for fluoride removal in the treatment plant. **Arsenic** is present at harmful levels in the outlets of Chandrawal 1 and Nangloi treatment plants, and **Cadmium** is above permissible levels in the outlet of the Okhla treatment plant. High **Total Iron** is present in the inlet water samples of Haiderpur, Nangloi, and Okhla WTPs, but only Okhla is unsuccessful in removing it.



Source: Central Groundwater Board and Central Pollution Control Board 2002

Map 3: Quality of Piped and Tanker Water supplied by DJB

Water from the treatment plants is distributed among different colonies in Delhi through a network of pipes and tankers by DJB. 26 such treated samples were collected from different parts of Delhi where 19 samples were of piped water and 7 samples were from tankers. From **Map 3** it is clearly visible that out of these 26 samples tested, 17 samples are biologically contaminated and 19 samples are chemically contaminated. Among the biologically contaminated samples 13 were from piped water and 4 from tanker water; similarly from the chemically contaminated samples 14 were from piped water and 4 from tanker water supply. This indicates that only 2 samples, i.e. tanker water from Kanjhawala in the west and piped water from the nearest outlet of Bhagirathi Treatment Plant in the north, are ***free from both biological and chemical contamination and may be said to be fit for drinking***. The detailed concentrations of contaminated samples are given in **Annexure 1.**

From the water sample analysis of the inlets and outlets of the DJB water treatment plants, it can be concluded that adequate measures have not been taken by DJB for proper functioning of the treatment plants and 6 out of 7 plants are supplying contaminated water to the people of Delhi. The research team tried to visit the treatment plants but failed to get permission from DJB officials in spite of several attempts over many months. Hence, the analysis of the functioning of the WTPs is limited to the results of the tests on inlet and outlet streams. This is a shortcoming of this study, but can be overcome only if and when DJB offers its full cooperation. However, what is significant is that tests of samples at 26 locations clearly demonstrate that contaminated water is supplied down the line to 34 of these locations. Hence, Delhi Jal Board cannot absolve itself of the responsibility of providing drinkable water free of biological and chemical pollutants to the citizens of Delhi – particularly those who belong to the weaker sections and do not have access to other sources of drinking water or to water purification technologies.

Status of Natural Water Sources

The analysis of 3 samples of surface water sources from canals and the river, and of 24 ground water samples from 11 deep bore wells, 12 shallow hand pumps, and 1 Ranney well, is given in **Table 4**. Out of the 3 surface water samples, 2 are *both* biologically and chemically non-potable while 1 from Murad Nagar canal is only free of chemical contaminants. All the 11 bore well samples are *both* biologically and chemically polluted. All the 12 hand pump samples are chemically non-potable, and only 3 are free of biological contamination. The Ranney well is both chemically and biologically polluted. Fluoride is almost universally present in all samples, while Lead, Arsenic, and Cadmium are occasionally present.

Table 4: Surface and Groundwater Analysis

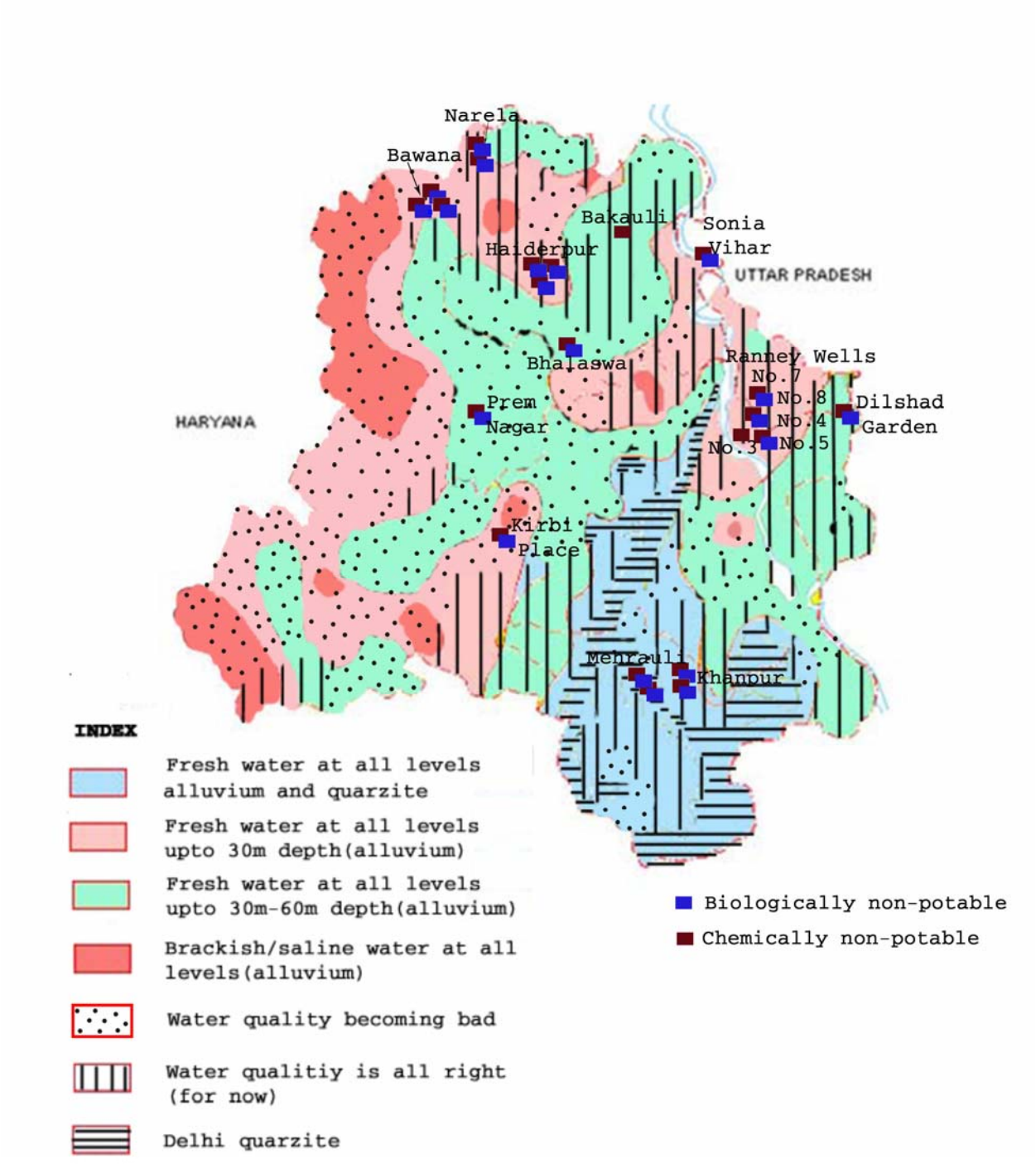
Location	Source of Water	Observations	Potability	
			Biological	Chemical
Surface water				
Bawana	Yamuna Canal	Faecal Coliform is present Total Iron is above permissible limit	**Non-Potable**	**Non-Potable**
Wazirabad	Yamuna River	Faecal Coliform is present Fluoride, Arsenic above permissible limit	**Non Potable**	**Non-Potable**
Murad Nagar	Murad Nagar Canal	Faecal Coliform is present	**Non Potable**	**Potable**
Ground water				
Bawana JJ colony	Bore well supply (1km distance)	Faecal Coliform is present Fluoride is above permissible limit	**Non Potable**	**Non-Potable**
Bawana JJ colony (F-block)	Submersible pump in tube well	Faecal Coliform is present Fluoride is above permissible limit	**Non Potable**	**Non-Potable**
Bawana JJ colony	Bore well (nearest point)	Faecal Coliform is present Fluoride is above permissible limit	**Non Potable**	**Non-Potable**
Swarna Jayanti Vihar JJC, Narela	Bore well (nearest point)	Faecal Coliform is present Fluoride is above permissible limit	**Non Potable**	**Non-Potable**
Swarna Jayanti Vihar JJC, Narela	Bore well (1km distance)	Faecal Coliform is present Fluoride, Lead above permissible limit	**Non Potable**	**Non-Potable**
Nirman Camp, Haiderpur	Bore well (nearest point)	Faecal Coliform is present Fluoride is above permissible limit	**Non Potable**	**Non-Potable**
Nirman Camp, Haiderpur	Bore well (1km distance)	Faecal Coliform is present Fluoride is above permissible limit	**Non Potable**	**Non-Potable**
Khanpur JJ Colony	Bore well (nearest point)	Faecal Coliform is present Fluoride Arsenic above permissible limit	**Non Potable**	**Non-Potable**
Khanpur JJ colony	Bore well (1 km distance)	Faecal Coliform is present Fluoride, Cadmium above permissible limit	**Non Potable**	**Non-Potable**
Nat colony, Mehraulli	Bore well (nearest point)	Faecal Coliform is present Fluoride is above permissible limit	**Non Potable**	**Non-Potable**
Nat colony, Mehraulli	Bore well (1 km distance)	Faecal Coliform is present Fluoride, Cadmium above permissible limit	**Non Potable**	**Non-Potable**

Haiderpur Nirman Camp	Hand pump	Faecal Coliform Present Fluoride is above permissible limit	**Non Potable**	**Non-Potable**
Bakauli village	Hand pump	Arsenic is above permissible limit	**Potable**	**Non Potable**
Bhalaswa JJ Colony	Hand pump	Faecal Coliform is present Fluoride, Arsenic above permissible limit	**Non Potable**	**Non-Potable**
Prem Nagar – III	Hand pump	Faecal Coliform is present Arsenic is above permissible limit	**Non Potable**	**Non-Potable**
Kalander Colony, Dilshad Garden	Hand pump	Faecal Coliform is present Fluoride, Iron, Lead above permissible limit	**Non Potable**	**Non-Potable**
Sonia Vihar	Hand pump	Faecal Coliform is present. Arsenic is above permissible limit	**Non Potable**	**Non-Potable**
Kirbi Place, Dhobi ghat	Hand pump	Faecal Coliform is present Fluoride, Arsenic above permissible limit	**Non Potable**	**Non-Potable**
Nanak sar	Ranney well	pH above permissible limit Faecal Coliform is present Fluoride Lead above permissible limit	**Non Potable**	**Non-Potable**
Vikas Marg	Ranney well No.7	Fluoride, Iron, Cadmium above permissible limit	**Potable**	**Non Potable**
Akshar Dham	Ranney well No.5	Faecal Coliform is present Fluoride, Iron above permissible limit	**Non Potable**	**Non-Potable**
Vikas Marg	Ranney well No.8	Faecal Coliform is present. Fluoride is above permissible limit	**Non Potable**	**Non-Potable**
Yamuna	Ranney well No.3	Faecal Coliform is present Fluoride, Iron above permissible limit	**Potable**	**Non Potable**
CWG village	Ranney well No.4	Fluoride, Iron, Cadmium above permissible limit	**Non Potable**	**Non-Potable**

Comparison of Test Results with CGWB data

The small dots in **Map 1.1** show bad water quality as depicted by the Central Ground Water Board and Central Pollution Control Board. When transposed against the groundwater quality results as found in this study and displayed in **Map 4**, it is found out that the sampling sites in the north-west and west at Bawana, Bhalaswa, Prem Nagar and Kirby Place show non-potable water quality for both biological and chemical analysis, which are in conformity with the *'water quality becoming bad*'' category in areas where fresh water was available at depths up to 60m, as declared by the CGWB **(Table 2)**. But there are areas like Narela and Haiderpur in the north-west, Sonia Vihar in the north, and Mehrauli and Khanpur in the south where the CGWB has identified these areas as having good water quality, but the actual quality has been seen to be not potable both biologically and chemically. In addition, ground water from Bakauli village in the north and the Ranney wells adjacent to the Yamuna, which the CGWB has depicted as safe water quality areas, is contradictory to the test results that show them to be biologically potable but chemically contaminated with high quantities of Fluoride, Total Iron, and Arsenic.

Thus, in many areas of the alluvial plains where the ground water was presumably observed to be fresh as late as 2002 by the CWGB, although at different levels up to 60m **(Table 2)**, are now seen to be heavily contaminated with Faecal Coliform and Fluoride, with traces of Arsenic, Lead, Cadmium, and Iron. In addition, even the quartzite areas of the Ridge, where fresh water was available at all levels, are also seen to be contaminated both biologically and chemically, especially near the confined aquifer of the Chhattarpur region. This indicates that the mere distinction between 'fresh' and brackish' is not adequate for the purposes of human health. Data has to be regularly and systematically collected and recorded for faecal, fluoride, pesticide, and heavy metal infiltration into ground water and the causes examined, if the ground water is to be protected as a source of drinking water. The information provided by CGWB on Delhi's water quality needs to be re-examined in this context, since the ground water is probably deteriorating much more rapidly than anticipated, leading to the possibility of serious water-borne diseases.



Source: Central Groundwater Board and Central Pollution Control Board 2002

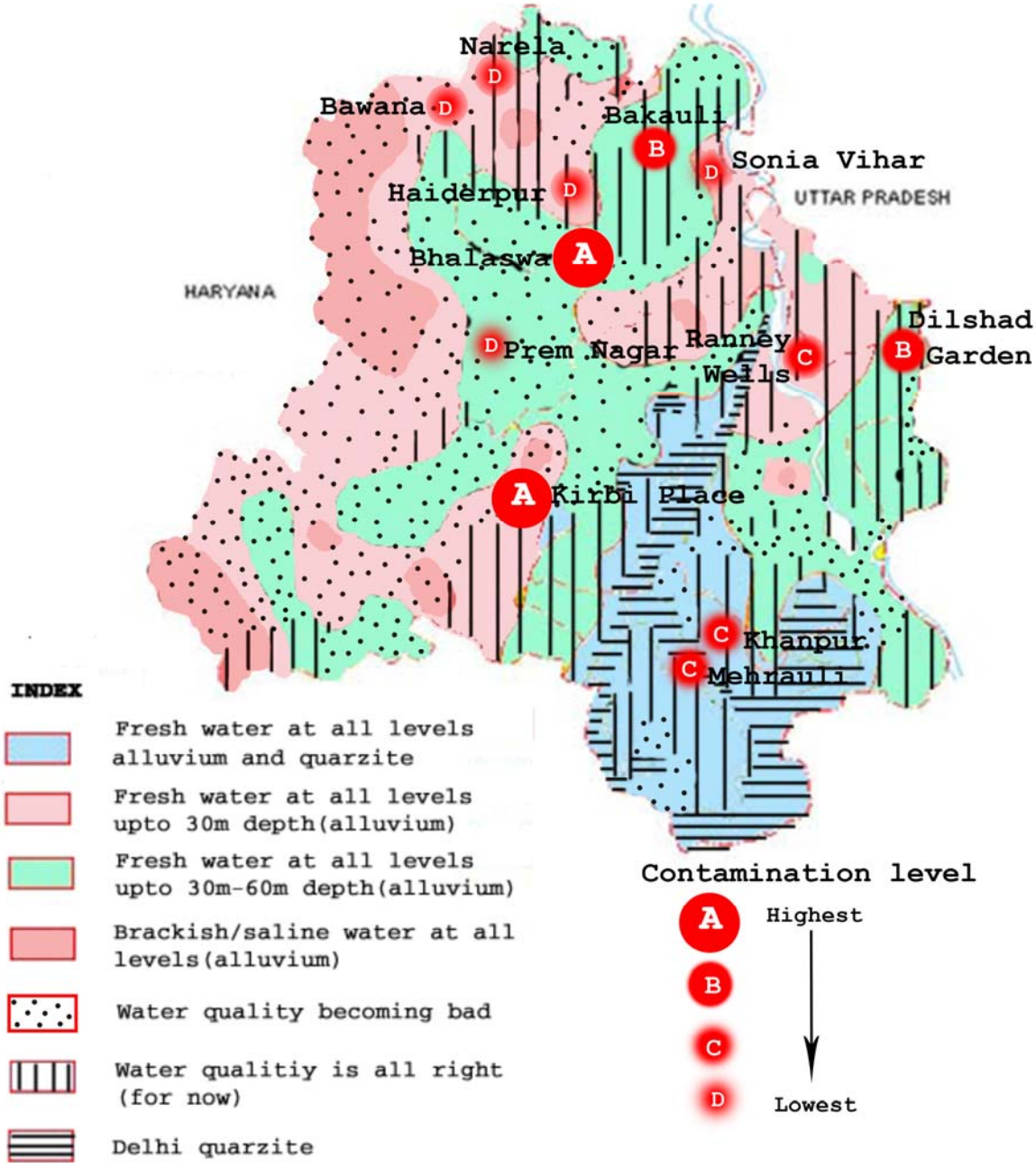
Map 4: Comparison of Groundwater Quality

Most Polluted Areas

Map 5 presents an attempt to gauge the overall status of bio-chemical contamination which is found by calculating (**Annexure 3)** the combined concentrations of the tested parameters. In order to do this an algorithm was developed to give greater weightage to parameters that occur more often and have more toxic impacts on living beings. Thus higher weightages were given to biological contaminants and fluoride, followed by pesticides and metals, in accordance with their toxicity and occurrence in the sampled waters. The sampling points were clustered according to their geographical locations and the level of contamination was computed for each cluster. The levels were then graded to give a rough assessment of what was the degree of pollution in a particular area and how it compared with other areas. The details are given in **Table 5**. The results have been displayed on **Map 5**.

As seen in the map the hydro-geological situation of Delhi is characterised by the occurrence of quartzite hard rocks in the Ridge area, surrounded by alluvial formations in the plains around the Ridge. These formations determine the availability of ground water in Delhi since the surface water infiltrates into the ground easier through alluvial deposits, but there are confined aquifers in the fractured rocks which also trap ground water in pockets. Thus, **Bhalaswa JJ Colony** and the **Kirby Place Dhobi Ghat** are areas falling in the highly permeable old alluvial plain to the north, and show the highest combined levels of contamination (***Grade A***). The CGWB has designated Kirby Place as lying within the brackish water zone and Bhalaswa as a freshwater zone with the water quality becoming bad, but this study reveals that these areas are highly contaminated by Fluoride, Faecal Coliform, Arsenic, and Pesticides.

The second highest level of contamination (***Grade B***) is found in **Bakauli Village** in the north and **Kalander Colony Dilshad Garden** in the east across the Yamuna, which have been characterised as freshwater zones with all-right water by CGWB, but where the levels of biological and chemical contamination are high and much of the water supply is from hand pumps installed in the alluvial plains. The third level (***Grade C***) is observed in the **Ranney wells** in the flood plain and in **Mehrauli** and **Khanpur**, both in the quartzite zone, and officially demarcated as good water quality zones. The lowest level (***Grade D***) is found in areas like Bawana, Narela, Haiderpur, Sonia Vihar under the brackish water zone, and Prem Nagar in a freshwater zone, where the main pollutants are Fluoride and Faecal Coliform.



Source: Central Groundwater Board and Central Pollution Control Board 2002

Map 5: Categorisation of Groundwater Contamination

Fluoride Confirmation

The levels of Fluoride were so significant during the colorimetric analysis of the samples in 2009, wherein 72% of the samples were found to contain the pollutant above permissible levels – particularly in ground water and the DJB water supply – that is was considered advisable to repeat the test through quantitative methods using the Ion Selective Electrode that covers the range from 0.1 to 1000 mg/l, as per the standard method given in ASTM D1179. Samples were collected again in February 2010 from the same sites as were sampled in April-June 2009 and tested for Fluoride concentrations with the aid of an Ion Selective Electrode. In order to confirm whether the earlier results using the colorimetric method was valid or not, the samples were also analysed qualitatively. The detailed results are given in **Annexure 4**.

The findings conclusively show that all the samples that were tested yield the same result when tested by either of the test methods. In other words, when the electrode gave a value higher than 1.5 mg/l (the Permissible level in absence of any other source) the colorimetric analysis also indicated an above limit level. Hence, *there is no basis for disputing the earlier findings of April-June 2009, before the monsoon season*.

However, the number of samples that contain fluoride above permissible levels reduces heavily from 72% to 17% only. But what is noticeable is that while all the surface water samples appear to be free of fluoride above this level, all the polluted samples come from ground water, and all the polluted sites lie in the older northern alluvial plains.

As far as the performance of the Water Treatment Plants of DJB are concerned, in this season both the Haiderpur and Okhla plants are able to treat fluoride to within permissible levels, primarily because the inlet surface (the canal in the case of Haiderpur) and ground (Ranney wells feeding the Okhla plant) water quality itself has improved.

These latter findings suggest that post-monsoon the fluoride concentration goes down in all sources, although it is detectable in ***all*** the samples. Hence, one could conclude that the contamination is mainly from surface waters that infiltrate into the ground and the rains significantly dilute the concentration, which builds up again during the lean summer months. Therefore, remedial action would have to focus on how to remove the fluoride at source itself.

Conclusions

The Objectives of this study were:

- ***To evaluate the quality of raw water in surface and ground water sources***
- ***To monitor the actual functioning of the water treatment plants***
- ***To evaluate the quality of drinking water after treatment***
- ***To check the quality of drinking water sources during the pre- monsoon season***

1. The ***quality of surface and ground water sources*** was estimated by analysing 3 samples of surface water sources and 24 ground water samples. Of the 3 surface water samples, 2 from the river and a canal are *both* biologically and chemically non-potable while only 1 from a canal is free of chemical contaminants. In ground water, all 11 bore well samples, 12 hand pump samples, and 1 Ranney well sample are *both* biologically and chemically polluted, except for 3 hand pumps that are free of biological contamination. Fluoride is almost universally present in all samples, while Lead, Arsenic, and Cadmium are occasionally present. There appears to be significant dilution of surface water contamination during the rains – as evidence by a post-monsoon repeat of the fluoride test using an Ion Selective Electrode – suggesting that the ground water is heavily affected by surface water quality.

2. It was not possible to ***monitor the actual functioning of the water treatment plants*** because the Delhi Jal Board would not give permission to visit, leave alone examine, the plants. However, the research team made an attempt to measure the quality of the waters at the inlet and the nearest outlet points. The results showed that the inlet water into all the 7 water treatment plants was non-potable (except for a couple of Ranney wells feeding Okhla), while the outlet quality at only two locations (Chandrawal-2 and near Bhagirathi)) could be considered to be potable, although in the case of the former the bacterial colony count was still very high. 3 treatment plants at Wazirabad, Nangloi, and Okhla are unable to remove Faecal Coliform, while 2 other plants at Chandrawal contribute a high bacterial colony count. Only in Chandrawal 1 does the outlet water contain adequate residual chlorine.

3. ***Drinking water from the treatment plants*** is distributed among different colonies in Delhi through a network of pipes and tankers by DJB. 26 such treated samples were

collected from different parts of Delhi, 19 were of piped water and 7 were from tankers. Of these, 17 samples were biologically contaminated (13 from pipes and 4 from tankers) and 19 were chemically polluted (14 from pipes and 5 from tankers). Only 2 samples, tanker water from Kanjhawala in the west and piped water from the nearest outlet of Bhagirathi Treatment Plant in the north, were free from both biological and chemical contamination and may be said to be fit for drinking.

4. The ***quality of drinking water sources*** across the entire city was assessed through tests on 53 samples selected from different hydro-geological regions. The results reveal that 38 samples had Faecal Coliform and in 22 of them there was also high Bacterial Colony Count, even though Residual Chlorine was definitively absent from only 9 of the 26 treated samples, indicating that the degree of chlorination is grossly inadequate. 37 samples had above permissible levels of Fluoride, pointing to the fact that there may be significant contamination from both natural as well as anthropogenic causes. There were 17 samples with Arsenic above the desirable limits, 8 samples with higher than desirable levels of Lead and 8 samples with higher than desirable levels of Cadmium. Organo-chloro Pesticides were found in 20 samples and Organo-phosphorous Pesticides in 10 samples.

The above findings raise two crucial questions:

A. The first question relates to the veracity of the data prepared by official agencies to project the quality of drinking water sources. When the status of water quality given by the Central Ground Water Board is transposed against the results found in this study, it is found out that many sites that are officially classified as having good water quality, actually show non-potable quality for both biological and chemical parameters. These sites are located not only in the alluvial plains where the ground water was observed to be fresh in as late as 2002 by the Board, and are now heavily contaminated with Faecal Coliform and Fluoride, with traces of Arsenic, Lead, Cadmium, Iron, and Pesticides, but even in the hard rock areas of the Ridge, where fresh water was earlier available at all levels. This indicates that the mere distinction between ‘fresh’ and brackish’ is not adequate for the purposes of human health and data has to be regularly and systematically collected and recorded for many more parameters.

B. The second question relates to the efficacy of the Delhi Jal Board water treatment plants. The data from this study shows that adequate measures have not been taken by DJB for the proper operation and maintenance of the treatment plants and 6 out of 7 plants are supplying contaminated water to the people of Delhi. Admittedly, the analysis of the functioning of the plants is limited because the research team could not actually visit and study the plants, and this is a shortcoming of this study, but it can be overcome only if and when DJB offers its full cooperation. What is significant is that tests clearly demonstrate that contaminated water is supplied down the line to many parts of the city. Hence, Delhi Jal Board has to be held accountable for providing drinkable water free of biological and chemical pollutants to the citizens of Delhi – particularly those who belong to the weaker sections and do not have access to other sources of drinking water or to water purification technologies.

If this study is able to facilitate the launch of a public-spirited effort to find the answers to the above two questions that are intimately linked to the health of the people of Delhi, then the efforts of the research team will have been sufficiently rewarded.

ANNEXURES

Annexure 1: Concentration of Chemical and Biological Parameters in Water Samples

No.	Location	Source of water	Chemical Analysis									Bacteriological Analysis		Heavy Metals (mg/l)			
			pH	EC (□mho-cm)	TDS (mg/l)	Residual chlorine (mg/l)	Chloride (mg/l)	Fluoride	Nitrate (mg/l)	Phosphate (mg/l)	Total Iron (mg/l)	Faecal Coliform	Bacterial Colony Count (colonies/ml)	Pb	Cd	As	Cr
1	Indira Camp, Begampur	DJB piped water supply	7.8	160	112	0	52	WPL	10	0.1	0.7	Present	300 with fungi	0.02	BDL	0.01	ND
2	Udham Singh Park, Wazirpur	DJB piped water supply	7.9	194	136	4	44	APL	1	0.1	3	Absent	None	BDL	0.003	0.07	ND
3	Haiderpur Nirman Camp	Hand pump	7.8	557	390	NA	76	APL	10	0	0	Present	460	BDL	0.003	BDL	ND
4	Haiderpur Village	DJB supply (Haiderpur WTP)	7.9	135	95	2	36	APL	3	0.1	0	Absent	60	0.288	BDL	0.02	0.002
5	Bawana	Yamuna Canal	8.3	137	96	NA	48	WPL	1	0.1	3	Present	46	BDL	0.002	BDL	ND
6	Bawana JJC	Bore well supply (1km from the bore well)	8.1	457	320	NA	44	APL	1	0.1	0	Present	>5000 with fungi	BDL	0.004	0.04	ND
7	Bawana JJC	Bore well (from points near the bore well)	8.1	459	321	NA	44	APL	0	0.1	3	Present	3000	BDL	0.004	0.001	ND

8	Bawana JJC (F-block)	Submersible pump	7.9	317	222	1	40	APL	0	0	0.1	Present	1320	BDL	0.001	BDL	ND
9	Swarna Jayanti Vihar JJ colony, Narela	Bore well (nearest point)	7.8	818	573	NA	200	APL	1	0.1	0.01	Present	640	BDL	0.002	0.008	ND
10	Swarna Jayanti Vihar JJ colony, Narela	Bore well (1km distance)	7.9	824	577	NA	224	APL	1	0.1	0.01	Present	440	0.151	BDL	0.009	ND
11	Bakauli Village	DJB piped water supply	7.6	801	561	0.5	480	WPL	0	0.1	0.1	Present	5000	BDL	0.007	0.016	0.036
12	Bakauli village	Hand Pump	7.3	1796	1257	NA	540	WPL	10	0	0	Absent	None	0.036	BDL	0.095	0.006
13	Bhalaswa JJC	DJB piped water supply	7.9	754	521	0	320	APL	0	0.1	1	Absent	1500	0.109	BDL	0.033	0.010
14	Bhalaswa JJC	Tanker water	8	872	610	0	220	APL	1	0.1	0.1	Present	2000	0.05	BDL	0.038	ND
15	Bhalaswa JJC	Hand pump	7.9	1279	895	NA	344	APL	0	0.1	0.7	Present	1000	BDL	0.003	0.08	0.048
16	Chandrawal WTP– 2	DJB piped water supply	8.1	201	141	4	92	WPL	1	0.1	0.7	Absent	2200	0.006	0.003	0.074	ND
17	Chandrawal WTP– 1	DJB piped water supply	7.8	194	136	4	68	WPL	1	0.1	0	Absent	2400	0.025	0.004	0.041	0.009
18	Outram Lines (JJC), Camp	DJB piped water supply	7.9	188	132	2	100	WPL	0	0	0.1	Present	1500 with fungi	BDL	BDL	0.067	0.003

19	Nirman Camp, Haiderpur	Bore well (nearest point)	7.7	994	696	NA	416	APL	1	0.1	0.01	Present	2400	BDL	0.001	BDL	ND
20	Nirman Camp, Haiderpur	Bore well (1km distance)	7.7	1005	704	NA	220	APL	10	0.1	0.01	Present	5000	BDL	BDL	0.06	ND
21	Mahavir Vihar, Kanjhawala	DJB piped water supply	8	140	98	2	40	APL	0	0.1	0	Absent	13	0.032	BDL	0.056	0.007
22	Mahavir Vihar, Kanjhawala	Tanker water	8.2	223	156	2	52	WPL	0	0.1	0.01	Absent	None	BDL	BDL	BDL	ND
23	Sabda ghewda JJC	Tanker water	8	135	96	1	58	WPL	0	0.1	0	Present	None	BDL	0.002	0.024	ND
24	Prem nagar – III	Hand pump	7.2	1244	622	NA	152	WPL	45	0	0	Present	3200	BDL	BDL	0.087	ND
25	Prem nagar – II	Tanker water	8	148	104	2	58	WPL	1	0.1	0.1	Absent	None	BDL	BDL	0.065	0.001
26	Nangloi WTP	DJB piped water supply	7.2	138	97	0.5	48	WPL	0	0.1	0	Present	40	BDL	0.004	0.06	ND
27	New Seelampur	DJB piped water supply	8.1	265	186	2	9	WPL	1	0.1	0.1	Present	None	BDL	0.002	0.009	0.004
28	Kalander Colony, Dilshad Garden	DJB piped water supply	8.1	91	64	2	52	APL	1	0.1	0.1	Present	320	BDL	0.002	0.013	0.014
29	Kalander Colony, Dilshad Garden	Hand pump	7.8	407	285	NA	156	APL	10	0.1	>3	Present	2200	0.226	BDL	0.016	0.00

30	Rajiv Camp – 1, Patparganj	DJB piped water supply	8.1	93	65	0.5	160	APL	0	0	0.01	Present	>1500	BDL	BDL	0.085	ND
31	Gokulpuri (near Bhagirathi)	DJB piped water supply	8	92	64	2	40	WPL	1	0	0.1	Absent	None	BDL	0.002	BDL	ND
32	Sonia Vihar, Pushta -1	Hand pump	8.1	251	176	NA	88	WPL	0	0.1	0.1	Present	2000	BDL	0.006	0.065	ND
33	Yamuna river	Raw water	9.1	172	120	NA	160	APL	0	0	0.01	Present	83	BDL	0.004	0.081	ND
34	Nanak sar	Ranney well	9.3	172	120	NA	64	APL	1	0	0.1	Present	53 with fungi	0.239	BDL	0.019	ND
35	Pappnkala JJC	DJB piped water supply	8.1	143	100	0	68	APL	1	0	0.1	Present	3000	0.215	BDL	0.027	ND
36	Pankha road, Uttam nagar	DJB piped water supply	7.9	142	99	0	600	APL	1	0.1	>3	Present	2400	ND	0.033	0.071	0.007
37	Najafgarh	Tanker water	8.3	139	97	0.2	64	APL	1	0	3	Absent	7	0.373	BDL	0.025	0.006
38	Deorala village	Tanker water	8.1	153	107	0	40	APL	0	0.3	0.1	Present	600	BDL	0.003	0.038	0.008
39	Naya Bazar, Najafgarh	DJB piped water supply	8.1	139	97	0	60	APL	0	0.1	1	Absent	600	BDL	0.006	0.016	ND
40	Kirbi place, Dhobi ghat	Hand pump	7.6	414	290	NA	120	APL	10	0	0.01	Present	1000	BDL	0.002	0.075	0.008
41	Kirbi place, Dhobi ghat	DJB piped water supply	7.9	137	96	0	60	APL	0	0.1	0.7	Absent	None	0.074	BDL	0.083	ND

42	Murad Nagar	Canal	8.7	226	158	NA	44	WPL	1	0.1	0.1	Present	158	0.01	0.02	BDL	0.012
43	Khanpur JJC	Bore well (nearest point)	7.6	353	247	NA	52	APL	10	0.1	0.1	Present	4000	0.007	ND	0.1	ND
44	Khanpur JJC	Bore well (1 km distance)	7.9	347	243	NA	76	APL	10	0.1	0.1	Present	340	0.005	0.027	0.020	ND
45	Nat colony, Chattarpur pahari, Mehraulli	Bore well (nearest point)	8.0	557	390	NA	184	APL	1	0.1	0.1	Present	400	0.001	ND	BDL	ND
46	Nat colony, Chattarpur pahari, Mehraulli	Bore well (1 km distance)	8.0	638	447	NA	172	APL	1	0.1	0.1	Present	2000	0.004	0.038	BDL	0.017
47	Nat colony, Chattarpur pahari, Mehraulli	Tanker water	7.9	538	377	0	120	APL	10	0.1	0.01	Present	1500	0.001	ND	BDL	ND
48	Okhla WTP	DJB piped water supply	7.9	92	65	1.0	68	APL	1	0	>3	Present	None	0.011	0.042	BDL	0.010
49	Vikash Marg	Ranney well No.7	8.1	405	380	NA	48	APL	10	0.1	>3	Absent	20	0.006	0.017	BDL	ND
50	Akshar Dham	Ranney well No.5	7.8	631	477	NA	188	APL	0	0.1	>3	Present	60	0.005	ND	BDL	ND
51	Vikash Marg	Ranney well No.8	8.1	477	1036	NA	28	APL	0	0.1	0.1	Present	500	ND	ND	BDL	ND
52	Near Yamuna	Ranney well No.3	7.6	1036	405	NA	40	APL	10	0.1	>3	Absent	15	ND	0.02	BDL	0.007
53	CWG village	Ranney well No.4	7.9	380	631	NA	240	APL	45	0.1	3	Present	50	0.003	0.047	BDL	0.008

WPL = within permissible levels; APL = above permissible levels; BDL = below detectable levels

Annexure 2: Concentration of Pesticides in Water Samples

No.	Location	Source of water	Organo-chloro Pesticides (µg/l)													Organo-phosphorous pesticides (µg/l)			
			α BHC	γ BHC	δ BHC	Endo sulphate	Hepatochlor-epoxide	Endrin aldehyde	44 DDD	44 DDT	Endosulphan I	Dieldrin	Aldrin	44 DDE	Endrin	Chloropyrifos	Cypermethrine	Monocrotophos	Any other Peaks
1	Indira Camp, Begampur	DJB piped water supply	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2	Udham Singh Park, Wazirpur	DJB piped water supply	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3	Haiderpur Nirman Camp	Hand pump	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.02	ND	ND
4	Haiderpur Village	DJB supply (Haiderpur WTP)	ND	ND	ND	ND	ND	ND	0.5	ND	0.16	0.42	ND	ND	ND	ND	ND	ND	ND
5	Bawana	Yamuna Canal	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6	Bawana JJC	Bore well supply (1km from the bore well)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7	Bawana JJC	Bore well (from points near the bore well)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

8	Bawana JJC (F-block)	Submersible pump	0.26	ND	ND	0.19	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
9	Swarna Jayanti Vihar JJC, Narela	Bore well (nearest point)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
10	Swarna Jayanti Vihar JJC, Narela	Bore well (1km distance)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
11	Bakauli Village	DJB piped water supply	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
12	Bakauli village	Hanp Pump	ND	ND	1.04	ND	ND	ND	ND	ND	ND	0.11	ND	ND	ND	ND	ND	ND	ND
13	Bhalaswa JJC	DJB piped water supply	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.39	0.09	0.12	ND
14	Bhalaswa JJC	Tanker water	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
15	Bhalaswa JJC	Hand pump	ND	ND	0.63	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.01	ND
16	Chandrawal WTP – 2	DJB piped water supply	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
17	Chandrawal WTP – 1	DJB piped water supply	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
18	Outram Lines (JJC), Camp	DJB piped water supply	ND	ND	ND	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND

19	Nirman Camp, Haiderpur	Bore well (nearest point)	0.32	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
20	Nirman Camp, Haiderpur	Bore well (1km distance)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
21	Mahavir Vihar, Kanjhawala	DJB piped water supply	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
22	Mahavir Vihar, Kanjhawala	Tanker water	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
23	Sabda ghewda JJC	Tanker water	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
24	Prem nagar – III	Hand pump	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.03	ND	ND	ND
25	Prem nagar – II	Tanker water	ND	ND	ND	ND	ND	ND	0.91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
26	Nangloi WTP	DJB piped water supply	ND	ND	0.59	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
27	New Seelampur	DJB piped water supply	ND	ND	ND	ND	1.82	0.23	ND	ND	ND	ND	ND	ND	ND	0.36	ND	0.7	ND
28	Kalander Colony, Dilshad Garden	DJB piped water supply	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
29	Kalander Colony, Dilshad Garden	Hand pump	ND	ND	ND	ND	0.72	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

30	Rajiv Camp – 1, Patparganj	DJB piped water supply	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
31	Gokulpuri (near Bhagirathi)	DJB piped water supply	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
32	Sonia Vihar, Pushta -1	Hand pump	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
33	Yamuna river	Raw Water	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
34	Nanak sar	Ranney well	ND	ND	ND	0.13	ND	ND	ND	ND	ND	ND	ND	ND	0.31	0.25	0.23	ND	ND
35	Pappnkala JJC	DJB piped water supply	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
36	Pankha road, Uttam nagar	DJB piped water supply	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
37	Najafgarh	Tanker water	ND	ND	0.19	ND	ND	ND	ND	ND	ND	ND	0.32	0.18	ND	ND	0.8	0.6	ND
38	Deorala village	Tanker water	ND	ND	ND	ND	0.15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
39	Naya Bazar, Najafgarh	DJB piped water supply	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
40	Kirby Place, Dhobi ghat	Hand pump	ND	ND	ND	ND	ND	ND	0.68	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
41	Kirbi place, Dhobi ghat	DJB piped water supply	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.1	ND
42	Murad Nagar	Canal	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
43	Khanpur JJC	Bore well (nearest point)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.46	ND	ND	ND	ND	ND

44	Khanpur JJC	Bore well (1 km distance)	ND	ND	0.32	ND	ND	ND	ND	ND	ND	ND	ND		ND	ND	ND	ND	ND
45	Nat colony, Chattarpur pahari, Mehraulli	Bore well (nearest point)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
46	Nat colony, Chattarpur, Mehraulli	Bore well (1 km distance)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.27	0.83	ND	ND	ND	ND
47	Nat colony, Chattarpur, Mehraulli	Tanker water	ND	ND	ND	ND	ND	ND	1.92	ND	ND	ND	ND	0.17	ND	ND	0.05	ND	ND
48	Okhla WTP	DJB piped water supply	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
49	Vikash Marg	Ranney well No.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05	0.01	ND	ND
50	Akshar Dham	Ranney well No.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
51	Vikash Marg	Ranney well No.8	ND	ND	ND	ND	0.34	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
52	Yamuna	Ranney well No.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
53	CWG village	Ranney well No.4	ND	0.74	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND = not detected

Annexure 3: Calculation of Contamination Levels

Weightage of parameters defined according to their results in groundwater samples

Parameters	Weightage
pH (0)	1
Lead	2
Cadmium	3
Organo-phosphorous Pesticides	3
Arsenic	4
Total Iron	4
Organo-chloro Pesticides	5
Total Colony Count	5
Fluoride	6
Faecal Coliform	7

Let,

'*z*' = concentration of the parameter

'*s*' = permissible limit of the parameter

'*w*' = weightage given to the parameter

Now,

Contamination of one parameter 'p' = $\{(z-s)/s\} \times w$

Total contamination of all 'n' parameters $= \sum_{p=1}^{n} \{(z-s)/s\} \times w$

Since Fluoride and Faecal Coliform is tested through colorimetry so, $(z-s)/s = 1$ for these two parameters

The sampling points were clustered according to their locations, and the Contamination Level was computed according to the above formula for all the sampling points in the cluster and the average level computed. This was then graded according to the following code:

A = > 3000

B = 2000 – 3000

C = 1000 – 2000

D = < 1000

The final results are given in **Table 4**.

Table 4: Contamination Levels of various Clusters

Location	$\sum_{p=1}^{n}\{(z\text{-}s)/s\} \times w$	Average contamination in Cluster	Level of contamination (A to D)
Bawana JJ colony	33	408	**D**
	31		
	1160		
Narela	13	13	**D**
	13		
Bakauli village	2899	2899	**B**
Bhalaswa JJ Colony	3163	3163	**A**
Nirman Camp, Haiderpur	70	573	**D**
	1615		
	33		
Prem nagar – III	108	108	**D**
Kalander, Dilshad Gdn	2129	2129	**B**
Sonia Vihar, Pushta -1	14	14	**D**
Kirbi Place, Dhobi Ghat	3410	3410	**A**
Khanpur JJ Colony	2323	1171	**C**
	18		
Chattarpur, Mehrauli	13	1392	**C**
	2771		
Ranney wells	1833	1220	**C**
	16		
	21		
	3709		
	1708		
	32		

Annexure 4: Fluoride concentrations in different seasons

No.	Location	Source of water	Chemical Analysis		
			Colorimetric April-June 2009	Quantitative February 2010	Colorimetric February 2010
1	Indira Camp, Begumpur	DJB piped water supply	WPL	0.286	WPL
2	Udham Singh Park, Wazirpur	DJB piped water supply	APL	0.336	WPL
3	Haiderpur Nirman Camp	Hand pump	APL	1.87	APL
4	Haiderpur Village	DJB supply (Haiderpur outlet)	APL	0.434	WPL
5	Bawana	Yamuna canal (Haiderpur/Nangloi inlet)	WPL	0.327	WPL
6	Bawana JJC	Bore well supply (1km from the bore	APL	7.96	APL
7	Bawana JJC	Bore well (from points near the	APL	11.6	APL
8	Bawana JJC (F-block)	Submersible pump	APL	2.3	APL
9	Swarna Jayanti Vihar JJ colony,	Bore well (nearest point)	APL	1.7	APL
10	Swarna Jayanti Vihar JJ colony,	Bore well (1km distance)	APL	1.76	APL
11	Bakauli village	DJB piped water supply	WPL	0.593	WPL
12	Bakauli village	Hand Pump	WPL	0.154	WPL
13	Bhalaswa JJC	DJB piped water supply	APL	0.258	WPL
14	Bhalaswa JJC	Tanker water	APL	0.212	WPL
15	Bhalaswa JJC	Hand pump	APL	1.77	APL
16	Chandrawal WTP– 2	DJB supply (Chandrawal outlet)	WPL	0.332	WPL
17	Chandrawal WTP– 1	DJB supply (Chandrawal outlet)	WPL	0.267	WPL
18	Outram Lines (JJC) Camp	DJB supply (Wazirabad outlet)	WPL	0.261	WPL
19	Nirman Camp, Haiderpur	Bore well (nearest point)	APL	1.63	APL
20	Nirman Camp, Haiderpur	Bore well (1km distance)	APL	1.7	APL
21	Mahavir Vihar, Kanjhawala	DJB piped water supply	APL	0.280	WPL
22	Mahavir Vihar, Kanjhawala	Tanker water	WPL	0.247	WPL
23	Sabda Ghewra JJC	Tanker water	WPL	0.231	WPL

24	Prem Nagar – III	Hand pump	WPL	0.499	WPL
25	Prem Nagar – II	Tanker water	WPL	0.241	WPL
26	Nangloi WTP	DJB supply (Nangloi outlet)	WPL	0.194	WPL
27	New Seelampur	DJB piped water supply	WPL	0.213	WPL
28	Kalander Colony, Dilshad Garden	DJB piped water supply	APL	0.216	WPL
29	Kalander Colony, Dilshad Garden	Hand pump	APL	0.554	WPL
30	Rajiv Camp – 1, Patparganj	DJB piped water supply	APL	0.261	WPL
31	Gokulpuri (near Bhagirathi)	DJB supply (Bhagirathi outlet)	WPL	0.256	WPL
32	Sonia Vihar, Pushta -1	Hand pump	WPL	0.289	WPL
33	Yamuna river	Raw water (Wazirabad inlet)	APL	0.220	WPL
34	Nanaksar	Ranney well (Okhla inlet)	APL	0.243	WPL
35	Pappankala JJC	DJB piped water supply	APL	0.250	WPL
36	Pankha road, Uttam nagar	DJB piped water supply	APL	0.191	WPL
37	Najafgarh	Tanker water	APL	0.197	WPL
38	Deorala village	Tanker water	APL	0.443	WPL
39	Naya Bazar, Najafgarh	DJB piped water supply	APL	0.286	WPL
40	Kirbi Place, Dhobi ghat	Hand pump	APL	1.1	WPL
41	Kirbi Place, Dhobi ghat	DJB piped water supply	APL	0.278	WPL
42	Murad Nagar	Canal (Bhagirathi/ Chandrawal inlet)	WPL	0.234	WPL
43	Khanpur JJC	Bore well (nearest point)	APL	0.316	WPL
44	Khanpur JJC	Bore well (1 km distance)	APL	0.298	WPL
45	Nat colony, Chattarpur pahari	Bore well (nearest point)	APL	0.499	WPL
46	Nat colony, Chattarpur pahari	Bore well (1 km distance)	APL	0.484	WPL
47	Nat colony, Chattarpur pahari	Tanker water	APL	0.378	WPL
48	Okhla WTP	DJB supply (Okhla outlet)	APL	0.256	WPL
49	Vikas Marg	Ranney well No.7 (Okhla inlet)	APL	0.219	WPL
50	Akshar Dham	Ranney well No.5 (Okhla inlet)	APL	0.236	WPL
51	Vikas Marg	Ranney well No.8 (Okhla inlet)	APL	0.200	WPL

52	Near Yamuna	Ranney well No.3 (Okhla inlet)	APL	0.322	WPL
53	CWG village	Ranney well No.4 (Okhla inlet)	APL	0.329	WPL

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