GOVT. OF INDIA
जल शक्ति मंत्रालय
MINISTRY OF JAL SHAKTI
जल संसाधन, नदी विकास और गंगा संरक्षण विभाग
DEPT. OF WATER RESOURCES, RIVER DEVELOPMENT & GANGA REJUVENATION

No.1-9/CGWB/NCR/TS/103

केंद्रीय भूमिजल बोर्ड
Central Ground Water Board
उत्तर मध्य क्षेत्र
North Central Region
Block-1, 4th Floor
Paryawas Bhawan, Jail Road,
Bhopal-462011
Fax: 0755-2760090
दिनांक : 15.01.2024

M.P. Pollution Control Board
BHOPAL M.P.
E/No.: 18/4922
Date : 18/1/24

प्रति
सदस्य सचिव
मध्य प्रदेश प्रदूषण नियंत्रण बोर्ड
पर्यावरण परिसर, इ-5, अरेरा कॉलोनी, भोपाल-462016

विषय:- माननीय एनजीटी द्वारा प्रकरण ओ.ए 732/2023 (PB) (Battling water woes in land of tragedy) के अन्तर्गत पारित आदेश दिनांक 22.12.2023 के सम्बंध में

रेफ:- दिनांक 09.01.2024 प्राप्त हुआ आपके पत्र क्रमांक 77/विधि/NGT(CZ)/प्रनिबो/2023

महोदय,

उपरोक्त विषय के संदर्भ में कार्यालय में प्राप्त पत्र के आधार पर, माननीय एनजीटी भोपाल बेंच द्वारा प्रकरण ओ.ए 732/2023 (PB) के अन्तर्गत पारित आदेश दिनांक 22.12.2023 के पालन करते हुए क्षेत्रीय कार्यालय भोपाल द्वारा Special Study Report titled 'Exploring the Heavy Metal Contamination and Basic water Quality Parameters around Union Carbide India limited (UCIL), Bhopal तैयार किया गया हे। इस संबंध में आपको उपरोक्त रिपोर्ट का एक प्रति प्रदान कि जा रही हे ।

DE(H)

ए के बिस्वाल
क्षेत्रीय निर्देशक

प्रतिलिपि:-

1. क्षेत्रीय अधिकारी, क्षेत्रीय कार्यालय, म.प्र.प्रदूषण नियंत्रण बोर्ड,भोपाल कि ओर से सूचनार्थ ।

Adv Mulist

18/1/24

ए के बिस्वाल
क्षेत्रीय निर्देशक

Special Study Report

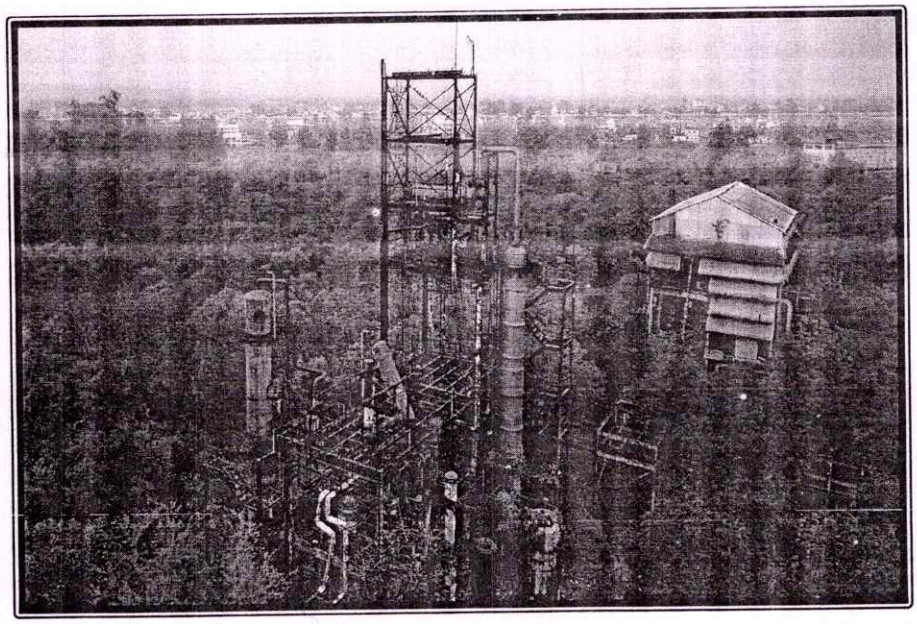
Exploring the Heavy Metals Contamination and Basic Water Quality Parameters around Union Carbide India Limited (UCIL), Bhopal

In the Matter of

ORIGINAL APPLICATION NO. 732/ 2023

w.r.t.

Hon'ble National Green Tribunal (Central Bench) Order dated 07.12.2023



Location: Union Carbide India Limited (UCIL)
District-Bhopal, M.P.

BEFORE THE HON'BLE NATIONAL GREEN TRIBUNAL

Data Analysis, Interpretation and Report writing
by
Dr. V. K. Kulshreshtha, Scientist-C
Mr. Tej Singh, Assist. Chemist

Sample Analysis
by
Mr. Rahul Vashishtha, Assist. Chemist
Mr. Jitendra Kumar, STA-Chem.

Sample Collection
by
Ms. Peshni Patel, Scientist-C
Mr. Jitendra Kumar, STA-Chem.
Ms. Adiba Khan, STA-Chem.

Abstract

In 1984, a tragic gas leak at the Union Carbide factory in Bhopal resulted in loss of lives, environmental damage, and adverse effects on flora and fauna. Despite challenges in quantifying the losses, various institutions have studied the immediate and long-term effects. In 2011, the Central Ground Water Board found saline groundwater due to geogenic mineral dissolution. Recently "The Hindu", a newspaper article highlighted groundwater contamination risks from poorly managed toxic waste at the UCIL premises. Prompted by this, the National Green Tribunal took Suo Motu action, summoning relevant CGWA and MP-PCB. The CGWA initiated a new investigation w.r.t. heavy metal contamination in groundwater near UCIL.

The primary objective of this investigation was to examine the potential groundwater contamination resulting from the consequences of the gas tragedy. The research employed field surveys and laboratory investigations, involving the collection of 72 groundwater samples (36 samples for basic parameters + 36 for heavy metals including U) from various directions within a 5 km radius of UCIL. The assessment of groundwater quality was conducted by comparing observations of different parameters against the Indian Standard (BIS, 1991) and WHO (1999).

Key findings revealed that pH values within the permissible range, Electrical Conductivity of Water (EC_W) below the BIS permissible limit, and absence of carbonate ions. Total Alkalinity (ALKT) values were within limits, and chloride concentrations indicated partial pollution. Nitrate concentrations exceeded the BIS desirable limit in 7 (four shallow and three deeper) out of 36 locations. Sulphate levels were below the BIS limit, while fluoride concentrations absolutely met BIS standards. Phosphate levels exceeded WHO permissible limits at two locations. Silica distribution varied, and nearly 99% of samples were categorized as hard or very hard water for household use. Some locations showed hardness (one shallow and two deeper), calcium, and magnesium concentrations exceeding BIS limits. Sodium concentrations at two locations exceeded WHO standards. Potassium concentrations in 27.77% locations were above WHO limits.

The study investigated concentrations of eighteen heavy metals in groundwater near UCIL. Iron concentrations exceeded BIS limits in eleven locations, reaching a maximum of 11.664 mg/l. Manganese pollution affected 8.33 % % of locations, exceeding the BIS limit. Aluminum concentrations reported within the BIS permissible limit. Zinc contamination was minimal, with only one location exceeding the BIS-acceptable limit but remained under permissible limit (15 mg/l). Arsenic concentrations were generally below BIS limits, except for one location.. Other tested parameters, including Silver, Boron, Molybdenum, Nickel, Copper, Selenium, Chromium, Cadmium, Barium, Mercury, Lead, and Uranium, fell within permissible limits. Strontium, not regulated either by BIS or WHO standards, was reported at concentrations from '0.198' to 2.223 µg/l with an average of 0.833 mg/l.

Furthermore, the **Gibbs (1970)** diagram suggested that most of the samples lie in the rock dominance zone, indicating that rock weathering is the primary source that controls groundwater chemistry and its evolution.

It may be concluded that the study area had saline ground waters due to the inherent geogenic high degree of mineral dissolution from parental material.

I.INTRODUCTION

In the tragic events of 1984, on the fateful night of December 2nd, a catastrophic gas leak occurred at the Union Carbide factory in Bhopal. The released gas, highly poisonous in nature, resulted in the loss of numerous human lives and livestock. Beyond the immediate human toll, the incident had far-reaching consequences, causing substantial environmental damage and adversely affecting the quality of flora and fauna in the surrounding areas.

Quantifying the extensive losses incurred by natural resources, including air and water in the city of Bhopal, due to the release of these poisonous gases has proven to be an intricate challenge. Despite this difficulty, various governmental entities, including state and central agencies, non-governmental organizations (NGOs), and autonomous bodies, have diligently undertaken efforts to comprehensively study both the immediate and long-term effects of the gas leakage. These studies aimed to provide a basis for future planning, enabling effective measures to overcome the adverse consequences of the gas leak.

A crucial aspect of post-gas tragedy investigation focuses on the examination of water quality in and around the affected area, notably the Union Carbide factory in Bhopal. The Madhya Pradesh State Pollution Control Board, Bhopal has been actively engaged in the routine monitoring of groundwater quality across various locations in Bhopal, with special attention to areas closely adjacent to the Union Carbide facility. This monitoring involves the collection of groundwater samples from representative hand pumps, dug wells, and tube wells.

In 2011, the Central Ground Water Board (CGWB), NCR, Bhopal, conducted a study around the Union Carbide factory area to assess groundwater quality. Samples were meticulously collected from hand pumps, tube wells, and dug wells at 12 different locations during July 2011. The study reported that the study area had saline groundwaters due to the inherent geogenic mineral dissolution from parental material.

A recent newspaper article dated 03.12.2023, published in ***"The Hindu"*** under the title ***"Battling Water Woes in the Land of Tragedy,"*** spotlights the critical issue of groundwater contamination. The article drew attention to the substantial volume of inadequately managed toxic wastes within the UCIL premises, highlighting the potential risk of contaminants seeping into the groundwater from the poorly contained toxic waste.

Prompted by this article, the National Green Tribunal (NGT), Principal Branch, New Delhi, took Suo Motu action, recognizing the urgent need for attention and remediation of toxic waste within the UCIL premises. Subsequently, the Hon'ble Tribunal summoned the

Central Ground Water Authority (CGWA) and Madhya Pradesh Pollution Control Board (MP-PCB) to appear before it on December 22nd.

In a proactive initiative to underline the significance of the environmental concern at hand, the New Delhi office of the Central Ground Water Authority (CGWA) directed its Bhopal regional office to undertake a new investigation into the presence of heavy metal contamination in the vicinity of Union Carbide India Limited (UCIL), Bhopal. Therefore, this study was initiated in response to the directives from the Regional Director, with the specific objective of assessing the extent of chemical contamination in groundwater surrounding residential areas closely situated to the Union Carbide India Limited Factory.

II. OBJECTIVE

The primary aim of this study was to evaluate the potential groundwater contamination in the proximity of the former UCIL plant, with a specific focus on the substantial volume of inadequately managed toxic wastes lying unheeded inside. Therefore, the purpose of this monitoring was to examine the likelihood of contaminants seeping from the plant into the groundwater.

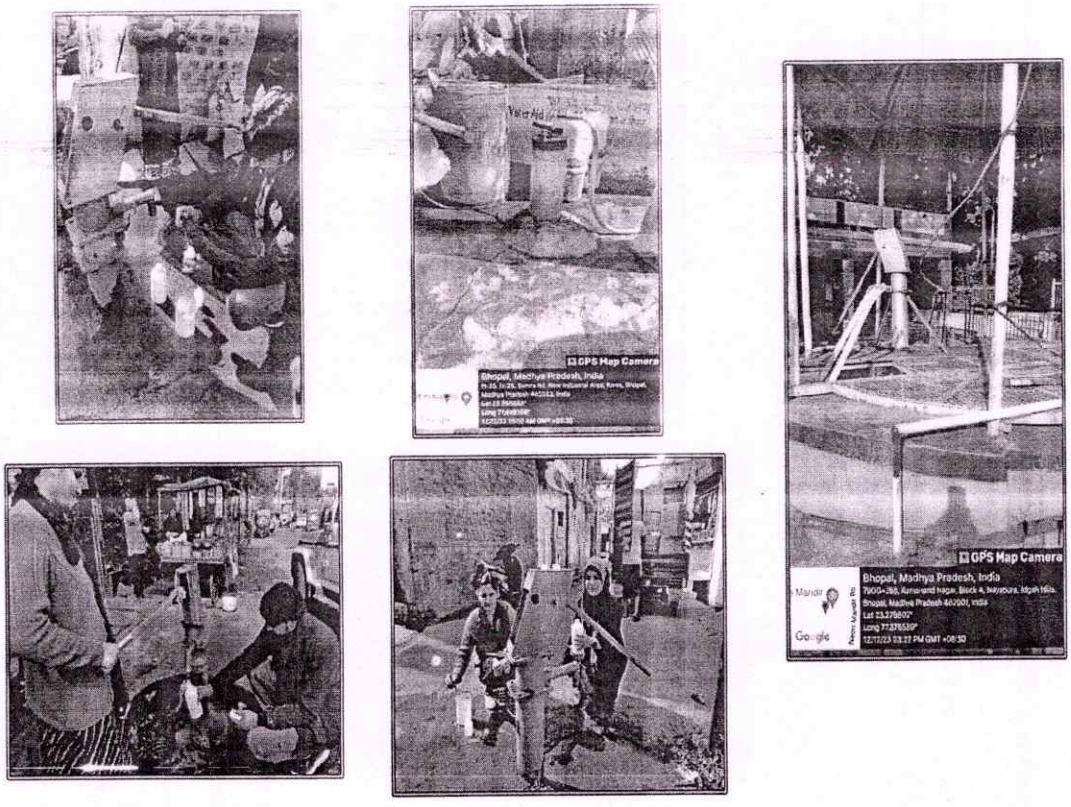
III. METHODOLOGY

As explained earlier, the main objective of the present study was to determine the potential groundwater contamination in the proximity of the former UCIL plant. In order to do the assessment, water samples were collected from groundwater sources used by the low-income community residing in the area. The sources of groundwater in the area were Hand pumps (HP), Tube wells (BW) and Dug wells (DW).

a. Sample Collection: To assess groundwater quality, a reconnaissance survey was conducted, scanning the geographical area surrounding UCIL. Grab samples were obtained from bore wells (BW), dug wells (DW), and hand pumps (HP). A total of 72 groundwater samples were systematically collected in duplicate, with 36 reserved for basic parameters and the other 36 acidified for heavy metals, including uranium. The sampling strategy encompassed a comprehensive network that covered all feasible sites within a 5 km radius of the UCIL factory premises. Sampling took place from December 12th to 14th, 2023 (See **Figure 1 & Annexure I**).Following the guidelines of the American Public Health Association (APHA, 2022), one-liter pre-rinsed airtight polythene bottles were used for sample collection after on-site filtration to eliminate turbidity, sealed securely with wax. **Figure 2** depicts a map of the study area, featuring the locations of groundwater sampling points indicated by red

dots. Detailed geographical coordinates of these sampling points can be found in **Annexure-I.**

Figure 1: Illustrates the collection of groundwater samples from the study area.



b. Analysis of Samples: The collected samples, adhering to proper handling protocols, underwent analysis at the Regional Chemical Laboratory, CGWB, Bhopal. The analysis included basic parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS), temperature (Temp. ^0C), carbonate (CO_3), bicarbonate (HCO_3), sulphate (SO_4), chloride (Cl), phosphate (PO_4), silica (SiO_2), nitrate (NO_3), total hardness (TH), calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K). Additionally, 18 specific heavy metals–namely, iron (Fe), zinc (Zn), manganese (Mn), cadmium (Cd), nickel (Ni), chromium (Cr), lead (Pb), aluminum (Al), boron (B), selenium (Se), silver (Ag), mercury (Hg), molybdenum (Mo), copper (Cu), Barium(Ba), Strontium(Sr), Arsenic (As) and uranium (U)–were analyzed. The determination of basic parameters followed Standard Methods (APHA, 2022) employing various volumetric methods, Flame-photometer (Systonics-128), and Spectrophotometer (Shimadzu, UV-1201). The analysis of heavy metals was conducted using ICP-MS (ThermoFisher Scientific, model icap RQ).

IV. RESULTS AND DISCUSSION

A. Appraisal of Ground Water Quality Based on Basic Parameters

The groundwater quality of the study area has been evaluated for different parameters, adhering to the specified limits established by the Bureau of Indian Standards **(BIS-2012)** and, for those parameters not covered under BIS, World Health Organization (WHO-1999) guidelines have been followed.

The chemical parameter of Electrical Conductivity (EC_W) took precedence as the key indicator to analyze spatial variations of salinity in different locations. The pH values ranged between 6.74 and 7.61, with an average of 7.11, and did not exceed the permissible limit for pH (6.5 to 8.5) as defined by **BIS (2012)**. The Electrical Conductivity of Water (EC_W) ranged from 502 to 2497 µS/cm at 25°C, with an average of 1209. All locations around Union Carbide India Limited (UCIL) exhibited EC_W values below the BSI's maximum permissible limit of 3000 µS/cm at 25°C **(Table 1 & 3)**.

The study found groundwaters in and around the UCIL area to be free from carbonate (CO_3^-) ions. However, fluctuations in bicarbonate (HCO_3^-) concentrations were considered for calculating Total Alkalinity (ALKT), which ranged from 164.96 to 559.88 (average 318.3). None of the locations had ALKT values exceeding the BIS permissible limit of 600 mg/l **(Tables 1 & 3)**.

Results indicated partial chloride contamination in the study area, with 19.44% of examined locations remained below the permissible limit (1000 mg/l). Chloride concentrations varied from 40 **(HP_7, Lalghati)** to 465 **(BW_4, Geetanjali College)** mg/l in samples covering the area close to UCIL **(Tables 1 & 3)**.

Nitrate (NO3-) concentrations exceeding the acceptable limit of 45 mg/l set by BIS were found in 7 out of 36 locations around UCIL. The range varied from 1 mg/l in DIG Banglow (DW_2) to 142 mg/l in Bhopal Railway Junction (HP_4). Among these locations, four were associated with shallow aquifers, while three were linked to deep aquifers.

The area around UCIL was free from sulphate, with 100% examined locations reporting concentrations below the BIS acceptable limit of 200 mg/l, ranging from 09 mg/l in Jhangirabad **(HP_{11})** to 95 mg/l in Bhopal Railway Junction **(HP_4)**. Fluoride concentrations in the circumventing area of UCIL were below the BIS permissible limit of 1.5 mg/l, as suggested by this study **(Tables 1 & 3)**.

There is no nutritional basis for the regulation of phosphate levels in the Bureau of Indian Standards for drinking water supplies. The World Health Organization **(WHO, 1999)** recommends 0.1 mg/l and 1.0 mg/l concentrations of PO_4^{3-} respectively as acceptable and permissible levels for drinking water. The findings revealed that phosphate levels exceeded

the WHO recommended permissible level of 1.0 mg/l at only two locations namely HP_5 (Mangalwara) with a maximum level of 2.33 mg/l and Golghar Museum (BW_{11}) with a level of 1.09 mg/l. Increasing phosphate levels, can be attributed to human activities such as farming and the disposal of sewage.

There are no agreeable primary or secondary contaminants limits of silica for drinking water prescribed either by the Bureau of Indian Standards (BIS) or any other slimier agency like US-EPA & WHO. The results of silica analysis in the study area revealed a non-uniform distribution, ranging from 8 mg/l (DW_1, Gufa Mandir) to 74 mg/l (BW_9, RGPV University), with an average concentration of 32 mg/l. This variation may be attributed to factors such as the water saturation deficit of the aeration zone, seasonal fluctuations in precipitation and temperature, bedrock reactivity, and mineral stability, as described by Dobrzynski (2005).

According to the classification provided by Sawyer & McCarty (1996), nearly 99% of the water samples were categorized as hard or very hard for household use. The hardness values ranged from 193 to 827 mg/l, with an average of 364 mg/l (*See* Tables 1 & 3); further three locations namely Bhopal Railway Junction (HP_4; shallow Aquifer), Geetanjali College (BW_4; Deep Aquifer), and Badwai(HP_{10}; shallow Aquifer) showed the hardness greater than BIS permissible limit (600 mg/l) respectively as 827,683 and 634 mg/l. Calcium content in water samples only from one location namely Bhopal Railway Junction (HP_4; shallow Aquifer) marginally exceeded the BIS maximum permissible limit of 200 mg/l, with concentrations reported as 212 mg/l. Around 27.77% of the locations recorded magnesium concentrations that exceeded the BIS acceptable limit of 30 mg/l, although they remained below the permissible limit of 100 mg/l(Tables 1 & 3).

The BIS did not provide specific limits for sodium; therefore, WHO standards were applied. The analysis revealed that sodium concentrations at two locations, namely Badwai (HP_{10}) and Bhopal Memorial Hospital (BW_{18}), exceeded the WHO limit of 200 mg/l, with an average concentration of 102 mg/l (Tables 1 & 3).

Similarly, no numerical BIS guideline exists for potassium, so WHO standards were followed. 27.77 locations (10 out of 36) recorded potassium concentrations above the WHO limit of 10 mg/l, with maximum, minimum, and average values of 40, 2.2, and 9.4 mg/l, respectively (Tables 1 & 3).

B. Appraisal of Ground Water Quality Based on Heavy Metals

The upcoming text describes the concentrations of eighteen environmentally significant heavy metals were investigated. These heavy metals include iron (Fe), manganese (Mn), aluminum (Al), zinc (Zn), arsenic (As), silver (Ag), boron (B), molybdenum

(Mo), nickel (Ni), copper (Cu), selenium (Se), chromium (Cr), cadmium (Cd), barium (Ba), mercury (Hg), lead (Pb), uranium (U) and Strontium(Sr). The presence and levels of above metals are of concern due to their potential environmental impact and toxicity.

In eleven out of thirty-six locations, iron concentrations exceeded the Bureau of Indian Standards (BIS) allowable limit of 1.0 mg/l. In these locations, the recorded iron levels were as follows: HP_1(1.436 mg/l), HP_2(1.023 mg/l), HP_3(5.383 mg/l), HP_4(1.657 mg/l), HP_6(4.707 mg/l), HP_7(10.073 mg/l), HP_9(1.879 mg/l), BW_{10}(4.398 mg/l), DW_4(3.981 mg/l), HP_{11}(11.664, maximum), BW_{16}(1.310) **(Tables 2 & 3)**. Out of these 11 locations, 7 locations were associated with shallow aquifers while 4 locations belonged to deeper aquifers.

The area surrounding Union Carbide India Limited (UCIL) is affected with partially manganese pollution as 8.33 % of locations (3 out of 36) recorded manganese concentration more than BIS's permissible limit of 0.3 mg/l. The maximum and minimum concentrations of 0.581 and 0.00 mg/l were recorded in BW_8 (Deeper Aquifer) and BW_{18} locations respectively (Tables 2 & 3). These three locations were associated with deeper aquifers.

Examinations revealed (refer to Tables 1 and 3) that within the study area, there is no evidence of arsenic pollution, as nearly all locations recorded arsenic concentrations below the permissible guideline set by the Bureau of Indian Standards (BIS) of 0.01 mg/l. The sole exception is the DW_3 location (Golghar Museum), where the arsenic concentration was slightly elevated at 0.012 mg/l **(Tables 2 & 3)**.

Additional tested parameters, including Silver(Ag), Aluminum (Al), Zinc(Zn), Boron (B), Molybdenum (Mo), Nickel (Ni), Copper (Cu), Selenium (Se), Chromium (Cr), Cadmium (Cd), Barium (Ba), Mercury (Hg), Lead (Pb), and Uranium (U), were observed to register concentrations consistently below their respective permissible limits across all locations (refer to **Tables 2 & 3**). This implied that the levels of these substances in the sampled locations fell within the acceptable range defined by the regulatory standards of **BIS (2012).**

Strontium is not a regulated contaminant under the BIS (2012); although not routinely tested for, strontium was reported in this study at concentrations from 0.198 to 2.223 mg/l with an average of 0.833 mg/l.

C. Mechanisms Controlling Groundwater Chemistry

Gibbs (1970) proposed a chemical diagram of mechanisms controlling the chemistry of groundwater to understand the relationship of the chemical components of waters with their respective aquifer lithologies. The diagram is divided into zones based on the contribution of recharging precipitation, rock/mineral weathering, and evaporation/ crystallization on the hydrochemistry. Various researchers have followed this type of chemical relationship of groundwater in different parts of India **(Srinivasan, 1992)**. The

discretion of the origin of the lithology has been explained by the following assumptions (**Day *et. al.*, 1998**):

(1) Atmospheric precipitation dominance waters should come from rocks which contain dominantly Na^+ and K^+, which are less soluble and producing only small quantities of TDS with a moderate to high Na/Ca+Na ratio.

(2) Rocks dominance waters (mineral weathering processes) show high concentrations of Ca^{2+}, Mg^{2+}, and HCO_3^- resulting in moderate TDS and moderate Na/Ca+Na ratio.

(3) Evaporation dominance waters show high concentrations of Na^+ and Cl^- ions and low concentrations Ca^{2+} and Mg^{2+} ions due to calcite precipitation resulting in high TDS and high Na/Ca+Na ratio.

Gibbs used two ratios in his diagrams, representing the **Ratio-I** for cations [(Na+K)/(Na+K+Ca)] and **Ratio-II** for anions [Cl/ (Cl+ HCO_3)] as a function of TDS which are widely employed to assess the functional sources of dissolved chemical constituents in waters either through precipitation-dominance, rock-dominance and evaporation dominance.

One of the major shortcomings with **Gibbs's (1970)** diagram is that no place for waters have been affected by domestic/industrial contamination or other sources of hydrochemical enrichment outside of the three sources outlined above since a lot of studies have shown the origin of the lithology away from the three major factors, namely, precipitation dominance, rock-water interaction, and evaporation-crystallization. It is probably on account of this reason that the diagram is often used together with other hydrochemical assessment diagrams such as Piper, Wilcox, etc. integrated with multivariate statistical analyses.

Lastly, to know the mechanisms controlling groundwater chemistry and the relationship of the chemical components of water from their respective aquifers, the chemical data about UCIL of Bhopal was plotted on Gibb's diagram (*See* **Figures 3a & 3b**). **Gibbs's ratio-1 (Cation)** ranged from 0.183 to 0.839 with an average of 0.513 whereas **Gibbs's ratio-2 (Anions)** varied from 0.144 to 0.258 with an average of 0.285 respectively.

Figures 3a and 3b indicate that all samples are situated within the zone characterized by rock dominance indicating that rock weathering is the primary source that controls groundwater chemistry and its evolution. Parent rock weathering facilitates the process by which dissolvable salts and minerals become incorporated with groundwater. Moreover, the long residence time of rock-water interaction also aids mineral dissolution (**Selvakumar *et. al.*, 2017**).

IV. Conclusion

In a concise summary, the study observed that the pH values of the groundwater were within acceptable limits, and the Electrical Conductivity of Water (EC_w) remained below the permissible limits set by the Bureau of Indian Standards (BIS). Additionally, carbonate ions were found to be absent. The investigation covered various parameters, including chloride, nitrate, sulphate, fluoride, phosphate, and silica.

The nitrate concentrations (NO_3^-) exceeding the BIS approved limit of 45 mg/l, were found in seven out of 36 locations surrounding UCIL. Of these, four were associated with shallow aquifers, and three were connected to deep aquifers. Nitrate is acknowledged as a well-established environmental contaminant originating from diverse human activities. Human-induced contributors encompass the production and utilization of nitrate fertilizers, the combustion of fossil fuels, and the discharge of domestic sewage (Gutierrez et. al., 2018; Ward, M. *et al., 2018* and Torres-Martinez, J. A. *et al.,* 2020)

Three locations namely HP_4; **shallow Aquifer, BW_4; Deep Aquifer** , and HP_{10}; **shallow Aquifer** showed the hardness greater than BIS permissible limit (600 mg/l) respectively as 827,683 and 634 mg/l.

Furthermore, the study highlighted into the concentrations of eighteen heavy metals, revealing elevated levels of iron and manganese in certain locations. Notably, strontium concentrations, which are not regulated by BIS, ranged from 0.198 to 2.223 mg/l, with an average of 0.833 mg/l.

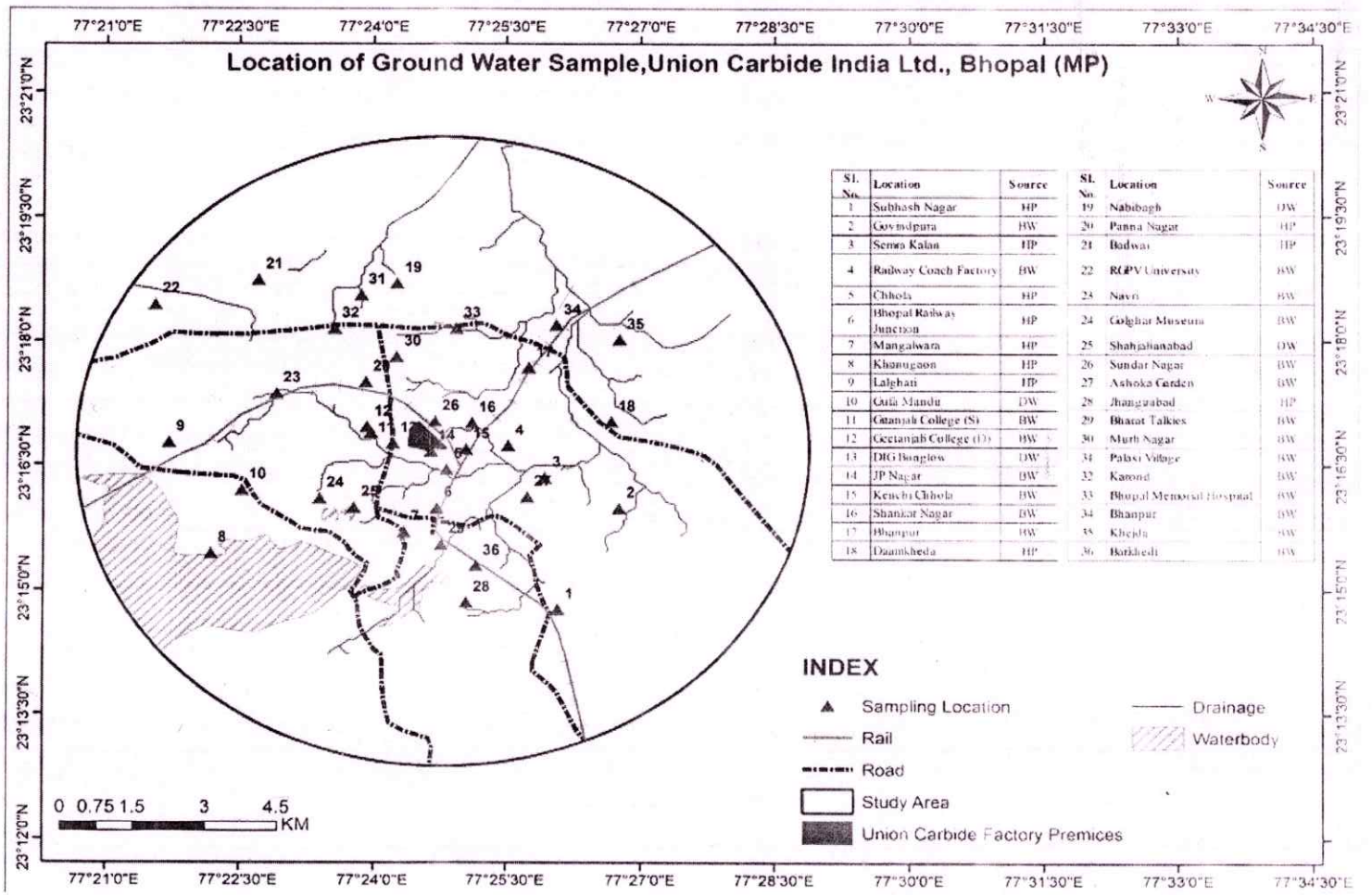
In eleven out of thirty-six locations, iron concentrations exceeded the BIS allowable limit of 1.0 mg/l. Among these 11 sites, 7 were connected to shallow aquifers (all through hand pumps), while 4 were affiliated with deeper aquifers (all accessed through bore wells). Iron naturally exists in the aquifer; however, concentrations in groundwater can be elevated due to the dissolution of components from ferrous boreholes and hand pumps. This refers to the gradual breakdown or disintegration of materials, specifically components from ferrous boreholes and hand pumps, which introduces additional iron into the groundwater.

The area surrounding Union Carbide India Limited (UCIL) is affected with partially manganese pollution as 8.33 % of locations (3 out of 36) recorded manganese concentration more than BIS's permissible limit of 0.3 mg/l.These three locations were associated with deeper aquifers. Examinations revealed that within the study area, there is no evidence of arsenic pollution, as nearly all locations recorded arsenic

concentrations below the permissible guideline set by the Bureau of Indian Standards (BIS) of 0.01 mg/l. The sole exception is the DW_3 location (Golghar Museum), where the arsenic concentration was slightly elevated at 0.012 mg/l (Tables 2 & 3).

The application of the Gibbs diagram in the analysis suggested that rock weathering played a pivotal role as the primary source influencing groundwater chemistry. This process, in turn, contributed to the presence of saline groundwaters in the study area.

Figure 2 Groundwater Sampling Points Map: Union Carbide India Ltd., Bhopal, Madhya Pradesh.



Sl. No.	Location	Source	Sl. No.	Location	Source
1	Subhash Nagar	HP	19	Nabibagh	DW
2	Govindpura	BW	20	Panna Nagar	HP
3	Semra Kalan	HP	21	Badwai	HP
4	Railway Coach Factory	BW	22	RGPV University	BW
5	Chhola	HP	23	Navri	BW
6	Bhopal Railway Junction	HP	24	Golghar Museum	BW
7	Mangalwara	HP	25	Shahjahanabad	DW
8	Khanugaon	HP	26	Sundar Nagar	BW
9	Lalghati	HP	27	Ashoka Garden	BW
10	Gufa Mandir	DW	28	Jhangvabad	HP
11	Gitanjali College (S)	BW	29	Bharat Talkies	BW
12	Geetanjali College (D)	BW	30	Murli Nagar	BW
13	DIG Bunglow	DW	31	Palasi Village	BW
14	JP Nagar	BW	32	Karond	BW
15	Kenchi Chhola	BW	33	Bhopal Memorial Hospital	BW
16	Shankar Nagar	BW	34	Bhanpur	BW
17	Bhanpur	BW	35	Khejda	BW
18	Daamkheda	HP	36	Barkheda	BW

Figure 3 Gibb's Diagram Illustrating the Mechanism Controlling Ground Water Chemistry for Sample Sites Belonging to UCIL, Bhopal.

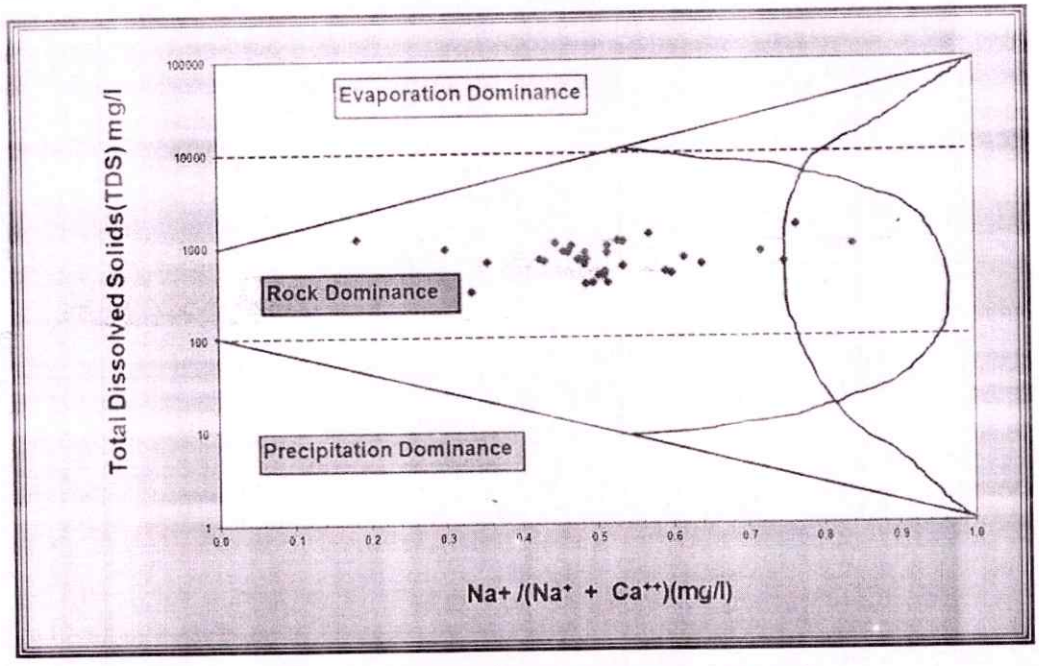


Figure 3 a (Ratio-II Cation)

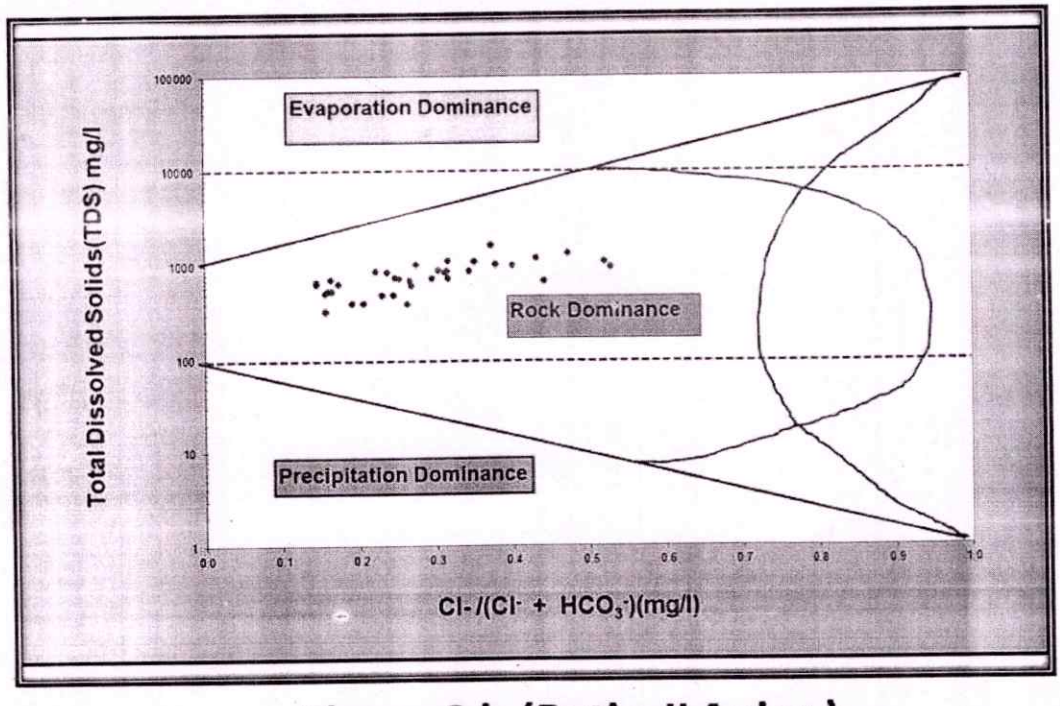


Figure 3 b (Ratio-II Anion)

Annexure I: List of Groundwater Sampling Locations.

Sl. No.	Location	Source	Type of Aquifer	Lat.	Long	Date of Collection	Address
1	Subhash Nagar	HP_1	S	23.24605	77.434716	12.12.2023	HP located in the Premises of Shamshan Ghat, Near Krishna Service Centre, Mehta Market.
2	Govindpura	BW_1	D	23.266389	77.446031	12.12.2023	BW located in Slum Area of Govindpura Industrial Area behind Yadav Tea Stall.
3	Semra Kalan	HP_2	S	23.272425	77.432282	12.12.2023	HP located in front of Ganesh Bhawan in the lane of Pawan Public School.
4	Railway Coach Factory	BW_2	D	23.273843	77.425424	12.12.2023	TW No. 12 of Railway Coach factory in front of Pump house No. 1; Near Water Supply Tank and Senior Section Engineer (Works) Office.
5	Chhola	HP_3	S	23.274109	77.413787	12.12.2023	HP located near Bharat Petroleum, in front of Ram Mandir, 50 m from Main Road.
6	Bhopal Railway Junction	HP_4	S	23.2664	77.411942	12.12.2023	HP located infront of Pipleshwar Mahadev Mandir Near Platform No. 6.
7	Mangalwara	HP_5	S	23.261599	77.405747	12.12.2023	HP Located in Front of Police Station Mangalawara.
8	Khanugaon	HP_6	S	23.257333	77.369683	12.12.2023	HP Located infront of Temple Near, Khanu Gaon.
9	Laighati	HP_7	S	23.279547	77.361819	12.12.2023	HP Located Opposite to Manubhawan Tekri Entry Gate Near SBI Branch.
10	Gufa Mandir	DW_1	S	23.27	77.37559	12.12.2023	DW Located in The Premises of Laighati Gufa Mandir (NHS Well).
11	Gitanjali College (S)	BW_3	S	23.28154	77.399615	12.12.2023	BW located in College Garden.
12	Geetanjali College (D)	BW_4	D	23.28273	77.3989	12.12.2023	BW located in Sport Complex of College.
13	DIG Bunglow	DW_2	S	23.279407	77.403673	12.12.2023	NHS Well
14	JP Nagar	BW_5	D	23.277756	77.41085	12.12.2023	In Front of Rajeev Gandhi Bal Udhyan, Water used for Gardneing Purpose.
15	Kenchi Chhola	BW_6	D	23.278124	77.417419	13.12.2023	BW in the House of Mamta Chocksey (Pico Shop).
16	Shankar Nagar	BW_7	D	23.283507	77.418568	13.12.2023	BW of Poonam Sharma in Nagar Nigam Colony in front of Iochapurti Mahadev Mandir.
17	Bhanpur	BW_8	D	23.294669	77.42932	13.12.2023	BW of Patal Ganga Bore Wells adjacent to Bharat Petroleum Pump
18	Daamkheda	HP_8	S	23.283767	77.444567	13.12.2023	200 mtr inside the village from Rajput Bhawan.
19	Nabibagh	HP_9	S	23.311641	77.404511	13.12.2023	NHS Well
20	Panna Nagar	HP_{10}	S	23.291739	77.398653	13.12.2023	HP located adjacent to Temple in Saeed Colony.
21	Badwai	BW_9	D	23.312368	77.378705	13.12.2023	HP located in front of Temple near Vaishno Devi HS School in Badwai Village.
22	RGPV University	BW_{10}	D	23.307436	77.359275	14.12.2023	BW located near Guest House and Girls Hostel of Rajeev Gandhi Technical University.
23	Navri	BW_{11}	D	23.28949	77.382052	14.12.2023	HP Loceted Near Mahakali Mandir Navri Village Near Aangan Wadi Kendra.
24	Golghar Museum	DW_3	S	23.268322	77.390149	14.12.2023	BW Located in the Premises of Golghar Museum.
25	Shahjahanabad	BW_{12}	D	23.266507	77.396477	13.12.2023	NHS Well
26	Sundar Nagar	BW_{13}	D	23.283852	77.411594	13.12.2023	BW located near Shiv Mandir in the house of Raja Singh.
27	Ashoka Garden	HP_{11}	S	23.26867	77.42904	14.12.2023	BW of Vardhman Green Park, 80 Feet Road.
28	Jhangirabad	BW_{14}	D	23.247465	77.417516	14.12.2023	HP located in Ahir Mohalla in front of Matri Chhaya House.
29	Bharat Talkies	BW_{15}	D	23.259057	77.4127277	14.12.2023	BW of MP Water Supply Near Patra Mandi Road in front Bhopal Wood Works.
30	Murli Nagar	BW_{16}	D	23.296865	77.4044092	14.12.2023	BW of Jaishree Auto Sales Petrol Pump Karond Circle Berasia Road.
31	Palasi Village	BW_{17}	D	23.30933	77.3978585	14.12.2023	In front of Small Temple.
32	Karond	BW_{18}	D	23.302549	77.392928	14.12.2023	BW of Vishwakarma Car Care Near Hiya Diagnostic and Sagar Gaire Karond
33	Bhopal Memorial Hospital	BW_{19}	D	23.302584	77.4156704	14.12.2023	BW of Yukti Traders and Dheeraj Jal Sewa Near Bhopal Memorial Hospital.
34	Bhanpur	BW_{20}	D	23.303234	77.4344388	14.12.2023	BW of Neeraj Marrige Garden located in Pashu Bazaar Bhanpur.
35	Khejda	BW_{21}	D	23.300351	77.4461524	14.12.2023	BW located in the house of Vinod Pal Kirana Store near Hanuman Mandir.
36	Barkhedi	BW_{22}	D	23.254822	77.4193222	14.12.2023	BW of Sajjad Hussain Indian Oil Petroleum Pump on Pul Bogda Road.

HP = Hand Pump, BW = Bore Well & DW = Dug Well

S= Shallow Aquifer & D= Deep Aquifer

Table 1: Presentation of Major Ions Concentrations in the Study Area.

S. No.	Parameters Analysed		Type of Aquifer	pH	EC	CO_3	HCO_3	ALKT	Cl	SO_4	NO_3	F	PO_4	SiO_2	TH	Ca	Mg	Na	K
	Desirable and Permissible limits of BIS standards			6.5 - 8.5	750 to 3000*	120 to 360**	244 to 732***	200 to 600	250 to 1000	200 to 400	45 to NR	1.0 to 1.5	0.1 to 1.0		200 to 600	75 to 200	30 to 100	200 (WHO)	10 (WHO)
	Location	Sources		at 25°C	µS/cm at 25°C	mg/l													
1	Subhash Nagar	HP_1	S	7.1	1106	0	421	345	82	40	13	0.41	0.03	13	342	107	18	57	40
2	Govindpura	BW_1	D	7.25	1544	0	378	310	252	44	36	0.34	0.04	35	480	119	45	117	8.4
3	Semra Kalan	HP_2	S	6.96	1554	0	470	385	178	52	66	0.39	0.02	28	460	156	17	134	2.9
4	Railway Coach Factory	BW_2	D	7.11	1332	0	378	310	198	72	6	0.1	0.03	23	351	137	2	126	2.2
5	Chhola	HP_3	S	7.02	1354	0	494	405	141	36	11	0.31	0.04	20	421	135	20	109	6.8
6	Bhopal Railway Junction	HP_4	S	6.94	1845	0	378	310	287	95	142	0.57	0.02	22	827	212	72	45	2.6
7	Mangalwara	HP_5	S	7.13	745	0	275	225	89	18	9	0.05	2.33	43	262	67	23	45	23.1
8	Khanugaon	HP_6	S	6.86	936	0	268	220	99	20	58	0.16	0.21	26	257	83	12	69	26.5
9	Lalghati	HP_7	S	6.86	502	0	214	175	40	18	5	0.05	0.09	68	203	53	17	24	2.9
10	Gufa Mandir	DW_1	S	6.74	605	0	201	165	72	44	8	0.05	0.11	8	203	61	12	51	7
11	Gitanjali College (S)	BW_3	S	6.91	812	0	378	310	72	14	8	0.3	0.08	17	243	85	7	87	2.3
12	Geetanjali College (D)	BW_4	D	6.93	2051	0	519	425	465	34	8	0.44	0.08	22	683	135	84	175	2.5
13	DIG Bunglow	DW_2	S	7.54	972	0	397	325	67	26	1	0.7	0.25	29	238	55	24	92	6.1
14	JP Nagar	BW_5	D	7.04	1301	0	519	425	161	12	1	0.41	0.08	24	406	113	30	116	3.4
15	Kenchi Chhola	BW_6	D	6.88	1669	0	458	375	248	48	104	0.22	0.07	23	545	182	22	142	4.5
16	Shankar Nagar	BW_7	D	6.9	1332	0	403	330	186	36	44	0.22	0.54	20	421	133	22	108	6.3
17	Bhanpur	BW_8	D	7.16	1125	0	409	335	139	18	10	0.28	0.1	25	351	131	6	93	3.5
18	Daamkheda	HP_8	S	7.17	1358	0	415	340	181	20	114	0.44	0.09	27	465	145	25	106	15.5
19	Nabibagh	HP_9	S	7.33	1074	0	354	290	129	20	24	0.52	0.1	48	351	99	25	71	4.3
20	Panna Nagar	HP_{10}	S	7.3	1155	0	415	340	136	34	11	0.4	0.09	38	307	81	25	126	4
21	Badwai	BW_9	D	7.14	2497	0	683	560	406	88	54	0.56	0.15	56	634	103	92	314	19.6
22	RGPV University	BW_{10}	D	7.33	612	0	220	180	57	30	14	0.35	0.16	74	193	55	13	50	4.4
23	Navri	BW_{11}	D	6.75	1056	0	256	210	203	26	4	0.16	0.09	25	366	143	2	75	3.8
24	Golghar Museum	DW_3	S	7.37	745	0	275	225	82	22	15	0.31	1.09	20	228	71	12	58	16.2
25	Shahjahanabad	BW_{12}	D	7.07	615	0	262	215	62	16	2	0.19	0.31	24	198	61	11	47	18.1
26	Sundar Nagar	BW_{13}	D	7.1	1685	0	336	275	364	36	3	0.91	0.1	18	475	131	36	145	5.2
27	Ashoka Garden	HP_{11}	S	7.61	1126	0	342	280	144	38	32	0.42	0.08	23	322	113	10	98	4.7
28	Jhangirabad	BW_{14}	D	6.97	777	0	336	275	62	9	2	0.31	0.09	24	208	59	14	69	19.6
29	Bharat Talkies	BW_{15}	D	7.1	983	0	390	320	82	10	3	0.12	0.34	37	297	83	22	60	18.2
30	Murli Nagar	BW_{16}	D	7.39	1030	0	409	335	69	32	9	0.76	0.13	56	223	40	30	112	5.2
31	Palasi Village	BW_{17}	D	7.17	1731	0	488	400	225	32	67	0.36	0.1	48	485	133	37	142	6.4
32	Karond	BW_{18}	D	7.31	1322	0	415	340	188	36	21	0.52	0.12	56	332	61	43	151	4.9
33	Bhopal Memorial Hospital	BW_{19}	D	7.57	1563	0	415	340	252	46	6	0.11	0.09	44	262	44	37	222	5.3
34	Bhanpur	BW_{20}	D	7.07	1125	0	354	290	163	26	36	0.32	0.11	30	351	109	19	98	5.5
35	Khajda	BW_{21}	D	7.04	1456	0	275	225	307	34	32	0.31	0.11	38	515	194	7	78	5.2
36	Barkhedi	BW_{22}	D	6.97	812	0	342	280	67	12	6	0.34	0.18	16	213	67	11	75	22.1

* Derived value determined from BIS limits given for TDS, ** Derived value determined from BIS limits given for Alkalinity & ***Derived value determined from BIS limits given for Alkalinity.

Table 2: Presentation of Heavy Metals Concentrations in the Study Area

S. No.	Parameters Analysed / Acceptable and Permissible limits of BIS standards / Locations	Sources	Type of Aquifer	B 0.5 to 1.0 mg/l	Al 0.03 to 0.2 mg/l	Cr 0.05 to NR mg/l	Mn 0.1 to 0.3 mg/l	Fe 1.0 to NR mg/l	Ni 0.02 to NR mg/l	Cu 0.05 to 1.50 mg/l	Zn 5 to 15 mg/l	As 0.01 to NR mg/l	Se 0.01 to NR mg/l	Sr mg/l	Mo 0.07 to NR mg/l	Ag 0.1 to NR mg/l	Cd 0.003 to NR mg/l	Ba 0.7 to NR mg/l	Hg 0.001 to NR mg/l	Pb 0.05 to NR mg/l	U 0.03 to NR mg/l
1	Subhash Nagar	HP_1	S	0.122	0.011	0.000	0.071	1.436	0.001	0.006	0.059	0.002	0.000	0.320	0.008	0.001	0.000	0.082	0.000	0.008	0.006
2	Govindpura	BW_1	D	0.110	0.018	0.000	0.001	0.042	0.001	0.004	0.011	0.005	0.006	1.107	0.007	0.018	0.000	0.151	0.000	0.002	0.014
3	Semra Kalan	HP_2	S	0.050	0.022	0.000	0.062	1.023	0.002	0.004	0.031	0.000	0.000	0.757	0.006	0.025	0.000	0.098	0.000	0.003	0.002
4	Railway Coach Factory	BW_2	D	0.025	0.051	0.000	0.020	0.425	0.001	0.001	0.031	0.000	0.000	0.806	0.005	0.026	0.000	0.099	0.000	0.020	0.003
5	Chhola	HP_3	S	0.062	0.004	0.000	0.082	5.383	0.002	0.006	0.340	0.000	0.000	1.070	0.000	0.000	0.000	0.099	0.000	0.003	0.010
6	Bhopal Railway Junction	HP_4	S	0.072	0.016	0.000	0.039	1.657	0.002	0.001	0.018	0.000	0.000	1.895	0.001	0.019	0.000	0.171	0.000	0.001	0.007
7	Mangalwara	HP_5	S	0.041	0.016	0.000	0.166	0.452	0.002	0.002	0.036	0.004	0.000	0.208	0.007	0.012	0.000	0.078	0.000	0.001	0.000
8	Khanugaon	HP_6	S	0.038	0.019	0.001	0.260	4.707	0.007	0.005	8.373	0.001	0.000	0.247	0.004	0.009	0.001	0.096	0.000	0.005	0.000
9	Laighati	HP_7	S	0.000	0.006	0.001	0.115	10.073	0.001	0.012	0.219	0.000	0.000	0.214	0.001	0.005	0.000	0.013	0.000	0.005	0.000
10	Gufa Mandir	DW_1	S	0.004	0.022	0.000	0.240	0.149	0.003	0.002	0.118	0.000	0.000	0.203	0.002	0.007	0.000	0.116	0.000	0.001	0.000
11	Gitanjali College (S)	BW_3	S	0.133	0.041	0.000	0.164	0.414	0.002	0.002	0.058	0.000	0.000	2.223	0.004	0.031	0.000	0.146	0.000	0.001	0.007
12	Geetanjali College (D)	BW_4	D	0.012	0.016	0.000	0.005	0.037	0.000	0.001	0.007	0.000	0.000	0.531	0.004	0.015	0.000	0.090	0.000	0.001	0.002
13	DIG Bunglow	DW_2	S	0.114	0.026	0.000	0.092	0.063	0.001	0.001	0.007	0.001	0.000	0.518	0.002	0.005	0.000	0.094	0.000	0.002	0.002
14	JP Nagar	BW_5	D	0.096	0.015	0.000	0.069	0.245	0.002	0.001	0.023	0.000	0.000	1.417	0.001	0.006	0.000	0.078	0.000	0.001	0.006
15	Kenchi Chhola	BW_6	D	0.035	0.010	0.000	0.018	0.059	0.001	0.002	0.014	0.000	0.000	1.394	0.001	0.009	0.000	0.161	0.000	0.001	0.013
16	Shankar Nagar	BW_7	D	0.059	0.018	0.000	0.480	0.067	0.002	0.007	0.006	0.001	0.000	1.215	0.002	0.012	0.000	0.145	0.000	0.001	0.006
17	Bhanpur	BW_8	D	0.043	0.053	0.000	0.581	0.419	0.003	0.012	0.038	0.001	0.000	1.121	0.001	0.003	0.000	0.179	0.000	0.003	0.004
18	Daamkheda	HP_8	S	0.090	0.000	0.000	0.031	0.001	0.001	0.001	0.876	0.000	0.003	1.620	0.000	0.000	0.000	0.029	0.000	0.000	0.004
19	Nabibagh	HP_9	S	0.059	0.016	0.000	0.008	0.034	0.001	0.002	0.022	0.000	0.001	0.813	0.001	0.012	0.000	0.046	0.000	0.001	0.002
20	Panna Nagar	HP_{10}	S	0.147	0.026	0.000	0.034	1.879	0.001	0.001	0.064	0.000	0.000	0.754	0.001	0.010	0.000	0.068	0.000	0.001	0.004
21	Badwai	BW_9	D	0.228	0.027	0.000	0.052	0.434	0.001	0.003	0.156	0.001	0.003	1.976	0.003	0.013	0.000	0.054	0.000	0.001	0.008
22	RGPV University	BW_{10}	D	0.036	0.007	0.000	0.001	0.030	0.000	0.010	0.013	0.000	0.000	0.198	0.001	0.042	0.000	0.073	0.000	0.001	0.000
23	Navri	BW_{11}	D	0.013	0.023	0.000	0.166	4.398	0.001	0.001	0.090	0.000	0.000	1.152	0.002	0.021	0.000	0.080	0.000	0.001	0.001
24	Golghar Museum	DW_3	S	0.025	0.133	0.000	0.116	0.611	0.002	0.001	0.010	0.012	0.000	0.234	0.011	0.004	0.000	0.190	0.000	0.001	0.003
25	Shahjahanabad	BW_{12}	D	0.038	0.025	0.000	0.473	3.981	0.001	0.001	0.015	0.005	0.000	0.285	0.002	0.007	0.000	0.161	0.000	0.001	0.000
26	Sundar Nagar	BW_{13}	D	0.122	0.018	0.000	0.163	0.118	0.003	0.001	0.007	0.001	0.000	1.353	0.001	0.005	0.000	0.143	0.000	0.001	0.005
27	Ashoka Garden	HP_{11}	S	0.034	0.000	0.000	0.007	0.956	0.001	0.000	0.010	0.000	0.000	0.608	0.000	0.001	0.000	0.055	0.000	0.000	0.002
28	Jhangirabad	BW_{14}	D	0.024	0.013	0.000	0.079	11.664	0.001	0.002	0.083	0.000	0.000	0.207	0.003	0.012	0.000	0.086	0.000	0.004	0.001
29	Bharat Talkies	BW_{15}	D	0.040	0.009	0.000	0.006	0.028	0.001	0.001	0.017	0.001	0.000	0.308	0.002	0.001	0.000	0.116	0.000	0.001	0.002
30	Murli Nagar	BW_{16}	D	0.100	0.008	0.000	0.010	0.075	0.000	0.001	0.028	0.000	0.000	0.392	0.001	0.002	0.000	0.033	0.000	0.001	0.002
31	Palasi Village	BW_{17}	D	0.068	0.006	0.000	0.036	1.310	0.002	0.001	0.484	0.000	0.000	1.289	0.001	0.006	0.000	0.118	0.000	0.001	0.003
32	Karond	BW_{18}	D	0.073	0.020	0.000	0.003	0.048	0.000	0.002	0.013	0.000	0.000	0.566	0.001	0.006	0.000	0.041	0.000	0.001	0.002
33	Bhopal Memorial Hospital	BW_{19}	D	0.127	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.409	0.000	0.000	0.000	0.017	0.000	0.000	0.003
34	Bhanpur	BW_{20}	D	0.050	0.000	0.000	0.005	0.000	0.001	0.000	0.021	0.003	0.000	0.986	0.000	0.000	0.000	0.055	0.000	0.000	0.005
35	Khejda	BW_{21}	D	0.044	0.008	0.000	0.003	0.097	0.001	0.001	0.031	0.000	0.000	1.374	0.001	0.010	0.000	0.080	0.000	0.001	0.003
36	Barkhedi	BW_{22}	D	0.029	0.000	0.000	0.024	0.000	0.001	0.001	0.018	0.001	0.000	0.230	0.001	0.000	0.000	0.124	0.000	0.000	0.002

NR= No Relaxation

Table 3 : The Summary of Water Quality Data of the Study Area Surrounding UCIL Compared with BIS (2012).

S. No.	Parameters	Min	Max	Avarage	Bureau of indian Standards (IS 10500:2012)	
					Acceptable Limit	Permissible limit in the absence of alternate sources
1	pH	6.74	7.61	7.11	6.5	8.5
2	Electrical Conductivity (ECw)	502	2497	1209	750*	3000*
3	Carbonate (CO_3)	0	0	0	120†	360†
4	Bi-carbonate (HCO_3)	201	683	376	244†	732†
5	Alkalinity	164.96	559.88	318.30	200	600
6	Chloride (Cl)	40	465	165	250	1000
7	Sulphate (SO_4)	9	95	33	200	400
8	Nitrate (NO_3)	1	142	27	45	No relaxation
9	Fluoride (F)	0.05	0.91	0.34	1	1.5
10	Phosphate (PO_4)	0.02	2.33	0.21	0.10#	1.0#
11	Silica (SiO_2)	8	74	32		
12	Total Hardness (TH)	193	827	364	200	600
13	Calcium (Ca)	40	212	104	75	200
14	Magnesium (Mg)	2	92	25	30	100
15	Sodium (Na)	24	314	102	200#	
16	Potassium (K)	2.2	40	9.4	10#	
17	Total Dissolve Solids (TDS)	326	1623	786	500	2000
18	Boron (B)	0.00	0.228	0.066	0.5	1
19	Aluminium (Al)	0.00	0.133	0.020	0.03	0.2
20	Chromium (Cr)	0.00	0.001	0.000	0.05	No relaxation
21	Manganese (Mn)	0.00	0.581	0.102	0.1	0.3
22	Iorn (Fe)	0.00	11.664	1.453	1	No relaxation
23	Nickel (Ni)	0.00	0.007	0.001	0.02	No relaxation
24	Copper (Cu)	0.00	0.012	0.003	0.05	1.5
25	Zinc (Zn)	0.001	8.373	0.315	5	15
26	Arsenic (As)	0.00	0.012	0.001	0.01	No relaxation
27	Selenium (Se)	0.00	0.006	0.000	0.01	No relaxation
28	Molybednum (Mo)	0.00	0.011	0.003	0.07	No relaxation
29	Silver (Ag)	0.00	0.042	0.010	0.1	No relaxation
30	Cadmium (Cd)	0.00	0.001	0.000	0.003	No relaxation
31	Barium (Ba)	0.013	0.190	0.096	0.7	No relaxation
32	Mercury (Hg)	0.000	0.000	0.000	0.001	No relaxation
33	Lead (Pb)	0.000	0.020	0.002	0.05	No relaxation
34	Uranium	0.000	0.014	0.004	0.03	No relaxation
35	Stromcium	0.000	0.006	0.0005	Not Mentioned	Not Mentioned

* = Drived fron BIS' TDS value, †= Derived form BIS' Alkalinity vaue & # = WHO Values

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