BEFORE THE NATIONAL GREEN TRIBUNAL
PRINCIPAL BENCH, NEW DELHI
OA.728/2023

News item appearing in Hindustan dated 30.11.2023 titled "Arsenic found in groundwater in 25 States, fluoride in 27 States: Govt"

INDEX

15.07.2025

New Delhi

Dated: 15.07.2025

Respondent No. 29

VINOD KUMAR DHAUNDIYAL
Administrator
Central Ground Water Authority
Government of India
Ministry of Jal Shakti
Department of Water Resources, RD & GR
New Delhi

Through

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(1)

BEFORE THE NATIONAL GREEN TRIBUNAL

PRINCIPAL BENCH, NEW DELHI
OA.728/2023

News item appearing in Hindustan dated 30.11.2023 titled "Arsenic found in groundwater in 25 States, fluoride in 27 States: Govt"

STATUS REPORT ON BEHALF OF Central Ground Water Authority (R-29)

It is most respectfully showeth:

I, Vinod Kumar Dhaundiyal S/o Lt Shri Ramesh Chandra Dhaundiyal Aged 50 Years, working as Administrator in Central Ground Water Authority having office at 18/11, Jam Nagar House, Man Singh Road, New Delhi the deponent herein do hereby solemnly affirm and state on oath as under:

1. That I am competent and authorized to file this status report on behalf of the Central Ground Water Authority (hereinafter referred to as the Answering Respondent) and the facts stated herein are true to my knowledge and as per the available records.

2. That I have gone through the contents of the above-captioned Original Application and am duly authorized to submit this status report on behalf of the answering respondent.

3. That during the hearing held on 19.11.2024, learned Counsel for CGWA submitted that a latest report based on subsequent samples would be filed covering all concerned States/UTs. The answering

The Seal of Oath Commissioner
SL. No.:- 01/2024
SANDHYA RANI GUPTA
App. By Delhi High Court
Period :- 01-04-2024
To 31-03-2026
Patiala House Courts, New Delhi-110001

(2)

respondent is filing the present status report regarding for further consideration of this Hon'ble Tribunal. In this regard, it is submitted that it had been decided by CGWB to carry out Baseline Water Quality Assessment to reflect a representative quality assessment for the entire country for which samples have been collected during 2025.

4. Furthermore, Central Ground Water Board (**CGWB**) has prepared a Standard Operating Procedure (SOP) on Ground Water Quality Data Analysis with the objective to analyze Groundwater quality data. The SOP is designed to guide personnel to ensure uniform protocol for ground water quality data analysis and uniform guidelines for ground water sampling, sample preservation, sample analysis techniques, quality control checks, data analysis, interpretation, reporting, data compiling and sharing of data and report. The SOP is enclosed as **Annexure-I.**

5. That as part of the Standard Operating Procedure (SOP) implementation, during the pre-monsoon season of 2025, the Regional Offices of the Central Ground Water Board (CGWB) have collected approximately 24,000 groundwater samples from designated monitoring locations across India for **Baseline Water Quality Assessment.** The samples will be analyzed for key physico-chemical parameters—including pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), major ions (such as Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, HCO_3^{-}, NO_3^{-}, F-)—as well as 18 heavy metals including Arsenic (As), Uranium (U), Lead (Pb), Chromium (Cr), and others, in accordance with BIS 10500:2012 drinking water standards. Analytical procedures will be carried out using advanced instrumentation such as Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and Atomic Absorption Spectroscopy (AAS).

(3)

6. The analysis is scheduled for completion by March 2026, and the consolidated national groundwater quality assessment report will be published by September 2026 and will be shared with the stake holders such as local government agencies (PHED, JJM, WRD, DoDW&S etc.), water management organizations, researchers, and environmental NGOs and District/State/UT administrations.

7. It is further submitted that CGWA will continue its periodic monitoring of groundwater quality as per its monitoring framework and will take appropriate action in coordination with the concerned agencies to address identified issues, curb contamination, and ensure sustainable management of groundwater resources.

8. That it is, therefore, prayed that the present Status Report may kindly be taken on record and this Hon'ble Tribunal may be pleased to pass such further orders or directions as may be deemed fit and proper in the interest of justice.

15.07.2025

DEPONENT

VINOD KUMAR DHAUNDIYAL
Administrator
Central Ground Water Authority
Government of India
Ministry of Jal Shakti
Department of Water Resources, RD & GR
New Delhi

I Identified The Deponent who has signed & thumb in my presence.

15 JUL 2025

Verification

I, Vinod Kumar Dhaundiyal, do hereby verify at New Delhi on 15-07-2025 the contents of the above paragraphs which are true to my own knowledge and/or are in the nature of legal submissions which I believe to be true and no material has been suppressed herewith.

CERTIFIED THAT DEPONENT
Shri/Smt./Km. ...
S/o W/o D/o ...
R/o ...
identified by Shri/Smt. ...
has solemnly affirmed before me at
Delhi on ..... at Sl. No. ...
that the contents of the affidavit which have
been read & explained to him are true and

15 JUL 2025 Oath Commissioner, Delhi

The Seal of Oath Commissioner
SL. No.:- 01/2024
SANDHYA RANI GUPTA
App. By Delhi High Court
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15.07.2025

DEPONENT

VINOD KUMAR DHAUNDIYAL
Administrator
Central Ground Water Authority
Government of India
Ministry of Jal Shakti
Department of Water Resources, RD & GR
New Delhi

1889

Standard Operating Procedure on Ground Water Quality Data Analysis

Step by step guidelines for Ground water quality data analysis

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation

Ministry of Jal Shakti

Standard Operating Procedure on Ground Water Quality Data Analysis

Prepared by

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Sh. Rakesh Devangan, Sc-D

Supervised by

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Acknowledgements

The committee members thank Sh. Rinkumoni Barman, STA (Chem), Dr Suparna Datta, Assistant Chemist and Dr Snigdha Dutta, STA (Chem) for providing valuable input and materials (figures, tables, etc.) from their scientific research publications. The Committee extends its gratitude towards Prof Shishir Gaur, IIT, BHU, for his critical and constructive review and for adding important scientific information to the SoP. The Committee also thanks Dr M.K. Sharma, Scientist F, NIH, Roorkee, for his extensive review. The Committee thanked the authors of the CGWB Framework entitled "*Framework for groundwater quality Monitoring in the Country*" for sharing their valuable information. In addition, the Committee thanked all the chemists of CGWB for their valuable comments and suggestions

Executive Summary

Water quality data analysis is the component of the monitoring process that turns collected data into useful information. Analyzing water quality data improves the understanding of the system being monitored and drives management action. Hence, it is essential to prepare a Standard Operating Procedure (SOP) for ground water quality data analysis.

The various monitoring networks to be followed in Central Ground Water Board is discussed in this SOP. The existing and new monitoring stations form the Background Monitoring Networks. Areas which show anomalous concentration of any basic/trace/geogenic /anthropogenic contaminants more than the permissible limit should be monitored regularly as Trend Monitoring Wells. Samples should be collected twice every year i.e., both during Pre-monsoon and post-monsoon. Areas where new geogenic contamination in ground water has been reported or anthropogenic influence has changed the ground water quality be monitored as Special Purpose Monitoring.

Geographical Information System (GIS) tools is used to map and visualize the distribution of various parameters geographically. Time series graphs are used for spotting connections between two or more water quality variables and to identify long-term trends and seasonal variations. Water quality Trend analysis for 5 year or 10 year district-wise/block-wise data is to be carried out during preparation of annual ground water quality report. Based on trend analysis, the reasons for ground water contamination may be assessed and shared with authorities for corrective action.

Suitability of water for drinking purpose is assessed based on BIS and WHO drinking water standards. Various water quality indices like Sodium Absorption Ratio (SAR), Percent Sodium and Residual Sodium Carbonate (RSC), graphical representation like Wilcox diagram and USSL diagram for irrigation suitability and Chloride – bicarbonate ratio for seawater intrusion, Bivariant plot and Scatter plots to visualize the relationship between two water quality parameters or contaminants are demonstrated in this SOP.

The additional parameters to be monitored such as Biochemical Oxygen Demand (BOD), COD, TOC, organic pollutant such as Pesticides, Dioxins, Volatile organic compounds (VOCs), Microbial contaminants like Bacteria, parasites, Total Coliform, Faecal coliform etc, Micro plastics and Pharmaceutical residues, Isotopes studies such asδ18O, δD, δ17O, 14C, 3H, 85Kr, 39Ar, 36Cl, and Radioactive elements like Uranium and Radon etc are placed in accordance with the CGWB uniform protocol for groundwater analysis and as per CGWB Vision 2047.

The SOP also communicates that groundwater quality report shall be shared with States/ UTs, DoDW&S and copy shall be marked to the district administration and any information regarding groundwater contamination shall be brought in to the public domain through CGWB website and NWIC.

(7)

Amendment Sheet

Sl	Page No	Section	Date of Amendment	Amendment made	Reasons
1					
2					
3					
4					
5					
6					
7					
8					

Contents

List of Tables and Figures

Tables

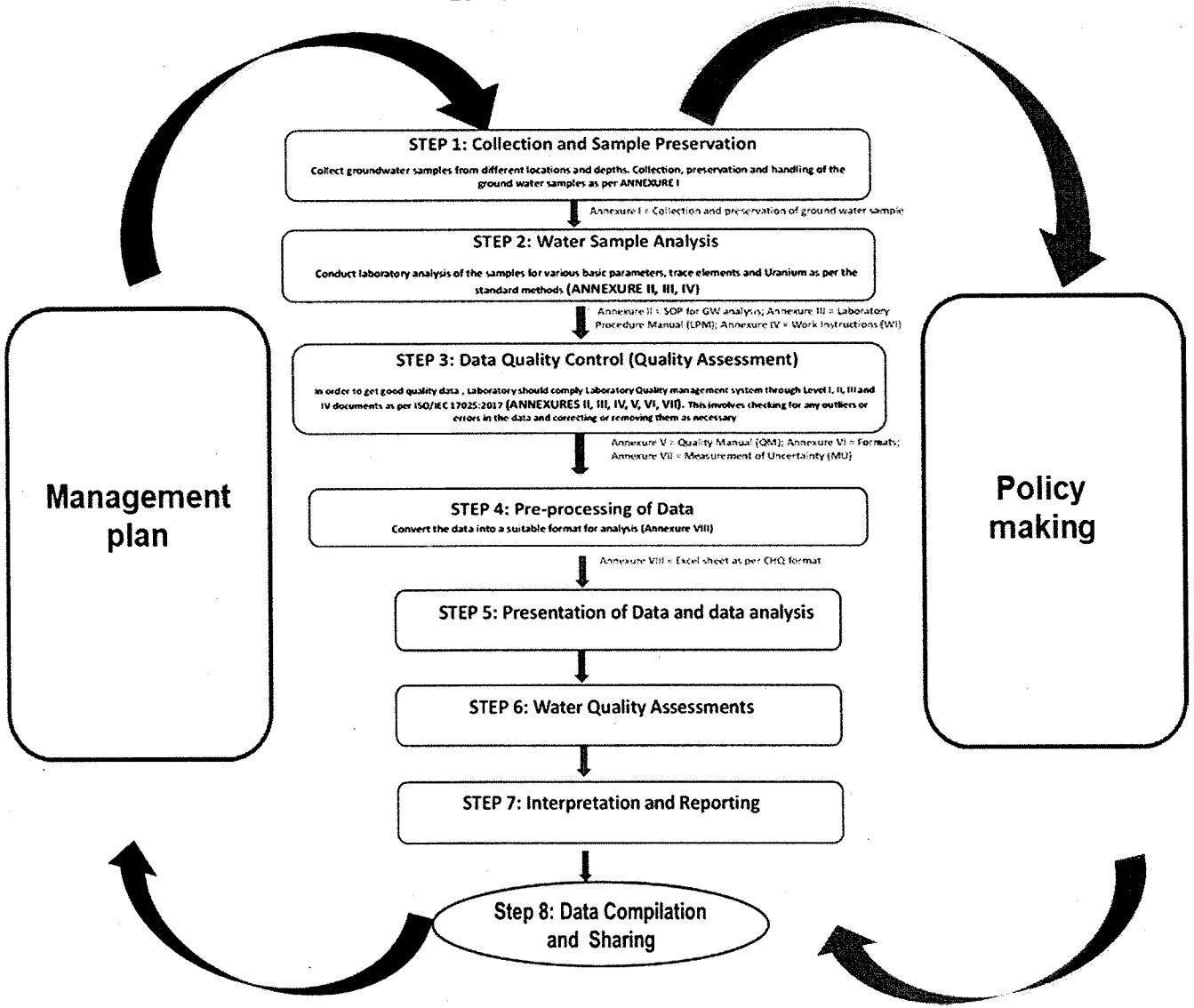
Figures

1. Introduction & Scope

Groundwater quality data analysis is crucial for the sustainable management of water resources. Effective groundwater management requires knowledge of the quality of available groundwater resources, identification of potential contamination sources, and development of strategies to prevent contamination. Overall, groundwater quality data analysis is critical for protecting human health and the environment, complying with regulations, promoting economic benefits, and ensuring sustainable water resource management. The Central Ground Water Board (CGWB) disseminates a quantum of groundwater quality data annually. CGWB ensures that significant ground water quality data is widely disseminated through various platforms to support informed decision-making and sustainable groundwater management.

This handbook aims to guide personnel to ensure uniform protocol for ground water quality data analysis and uniform guidelines for ground water sampling, sample preservation, sample analysis techniques, quality control checks, data analysis, Interpretation, reporting, data compiling and sharing of data and report. The subsequent sections outline protocols for new ground water monitoring framework, ground water sampling, their analysis methodology, data preprocessing, data analysis, Interpretation, reporting, data compilation and sharing. This handbook on ground water quality data analysis is a concise portion of Ground *Water Quality data analysis Report* and subject to modification when necessary to adapt to diverse site conditions, equipment constraints, or procedural limitations.

2. Flowchart for Methodology (SOP) on Groundwater Quality data analysis



- Step by step guidelines for Ground water quality data analysis
- Step 1 to Step 3 related to Ground Water Quality monitoring and analysis (refer documents Annexure I to Annexure VII following NABL protocols as per ISO/IEC 17025:2017).
- Data analysis part starts from Step 5 to Step 7, For detail explanation refer **Ground Water Quality data analysis Report (GWQDA-Report)**

3. Collection and Sample Preservation

The protocol for new groundwater quality monitoring framework is illustrated in Table 1 and 2. Criteria for Special Purpose Monitoring or Criteria for selection of Special purpose/New Hotspot monitoring should be in accordance to Figure 1. Ground Water Monitoring and analysis should be done as per protocol illustrated in Table 1.

Table 1: Sampling frequency and parameters for analysis

Type of Water Quality Monitoring	Sampling frequency	Parameters for analysis
Background Monitoring (All WQ Stations)	**Once every 5 years** **(PRE-MONSOON SEASON)**	**i) 15 major parameters** pH, EC, Ca^{2+}, Mg^{2+}, TH, Na^{+}, K^{+},F^{-}, CO_3^{2-}, HC Cl^{-}, NO_3^{-}, SiO_2, PO_4^{3-} **ii) minimum 5 trace elements** Fe, As, U plus any two-trace metal as per need of the respective region.
Trend Monitoring Minimum 25% of WQ stations (All locations where constituents exceed the permissible limit of IS 100500:2012 drinking water standards need to be study before selection of Trend Monitoring)	**Every Year** **(BOTH PRE AND POST-MONSOON SEASON)**	
Special Purpose Monitoring/ New Hotspot monitoring	**Only under special studies** (One time study, duration: region's need based) **(BOTH PRE AND POST-MONSOON SEASON)** Detailed sampling on a grid of 2 km x 2 km (From area falling within a radius of 5 km from locations from where the Contaminants like Arsenic, Uranium, Lead, Cadmium, Chromium, Selenium etc.)	

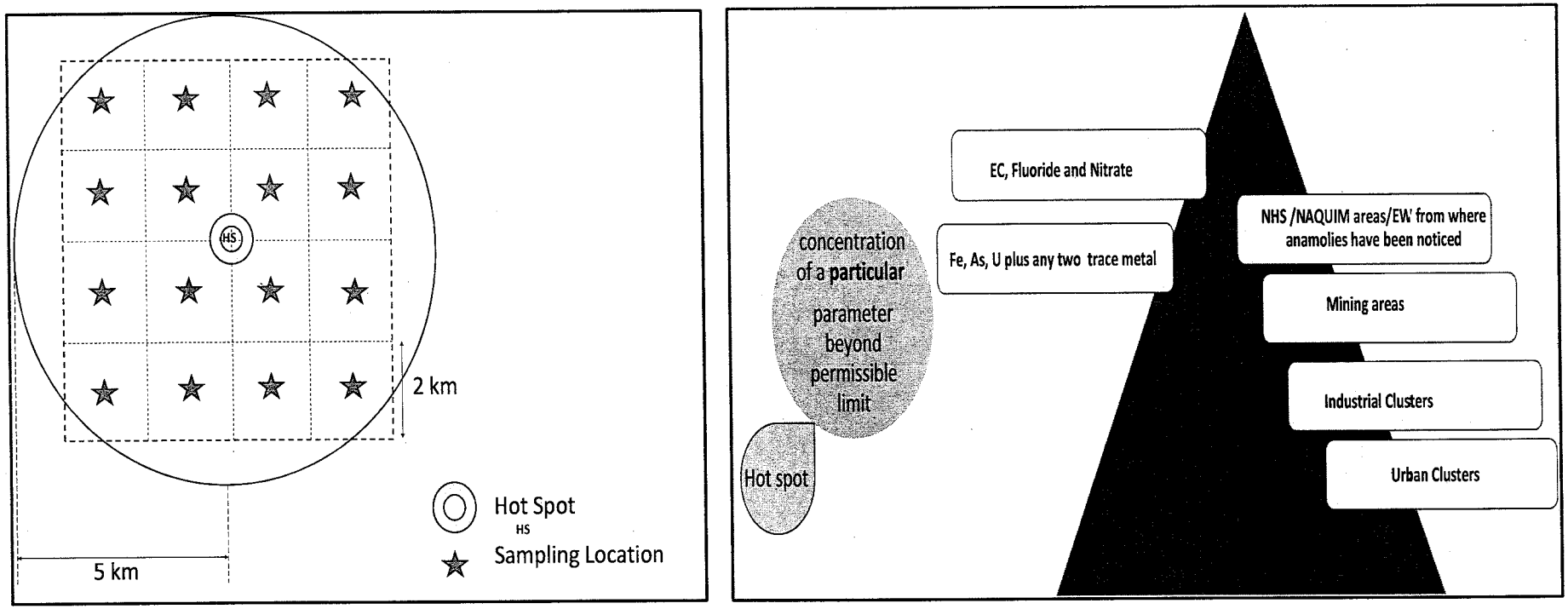


Figure 1: Criteria for Special Purpose Monitoring/New Hotspot monitoring

- **All the existing and new monitoring stations form the Background Monitoring.**
- **Stations/Areas which show anomalous concentration of any basic/trace/geogenic/anthropogenic contaminants more than the permissible limit should be monitored regularly and termed as Trend Monitoring Wells.**
- **In New Hotspot monitoring special focus should be taken up in areas where new geogenic contamination in ground water has been reported or anthropogenic influence has changed the ground water quality**

Table 2: Criteria for selection of new Ground Water Quality Monitoring Stations

S. No.	Thematic Area	No of water quality monitoring stations recommended
1	Urban Areas	One (1) Groundwater Quality GWQ monitoring stations in every 5 sq km
2	Agricultural belts with intensive application of chemical fertilizers	One (1) GWQ monitoring stations every 50 sq km area
3	Industrial areas	WQ Monitoring station in 1 x 1 Km grid.
4	Mining Areas	WQ Monitoring station in 1 x 1 Km grid.
5	Major Landfill sites	To establish well(s) within 100 m. from the landfill sites both in the upstrean downstream side.
6	Sites where surface water quality is being monitored by CWC or CPCB	One (1) GWQ monitoring stations for Groundwater quality
7	Salt water intrusion	Monitoring stations are needed to be established along and across the coast l
8	Recharge Site/Special intervention Areas	To establish well(s) both in the upstream and downstream side and within 10 such sites.

3.1 Ground Water Sampling and preservation techniques

The sample collector should take utmost care while collecting, storing and handling the samples to the laboratory. The Laboratory should further maintain the recommended conditions and follow the parameter wise timeline for analysis as per Table 3.

Table 3. Summary of Sampling and Handling Requirements

Determination	Container	Minimum Sample Size, mL	Preservation	Maximum Storage Recommended	Analysis Standard Method
Field parameters (pH, EC, Temp etc.)				• Analyze immediately	APHA, 2021, 24th Edition/ IS standard IS 3025
Basic Parameters	PE	1000		• All basic parameters must be analysed within 3 months	
Heavy metals	PE (A)	500, 1000 (using AAS) 60 (using ICPMS)	For dissolved metals filter immediately, add HNO_3 to pH<2	• 6 months	

PE = Polyethylene or equivalent

PE(A) = Polyethylene acid wash

Note: Ground Water samples should be transported to Regional Chemical Laboratory as soon as possible, preferably within 48 hours. Sample should be refrigerated below 6°C for Temperature sensitive constituents.

Note: **Important information on the sample bottle/container should include**

1. **Sample code number**
2. **Location**
3. **Source and type of sample**
4. **Date of sampling**
5. **Preservation carried out on the sample**
6. **Field Officer Name**

Table 4. Sample submission format

Sl No	Details of Ground Water Quality Monitoring Stations											Field parameters					No. of samples submitted to analyze						
	Well No.	State / UT	District	Block/ Taluka	Village	Station Name/ Location	Longitude (DD)	Latitude (DD)	Source of Sample	Depth of Sample	Sampling Date	Temp (°C)	pH	EC (µS/cm)	DO (mg/l) (Optional for Pollution/Special study)	ORP (mV) (Optional for Pollution/Special study)	Basic	Basic (Refrigerated sample)	Fe+As	Heavy Metal	U	Isotope	Any other

The above sample submission format (excel sheet) should be submitted in hard as well as in soft copy while submitting the ground water samples to Regional Chemical laboratory.

Geographical coordinates of a station must be accurate for its location.

4. Water Sample Analysis

Laboratory analysis of the samples for various basic parameter, trace elements and uranium as per the standard method illustrated in Table 5.

Table 5. Specifications of standard methods used for various parameters.

SL. NO.	DETAILS	TECHNIQUE/METHOD	INSTRUMENT/ TECHNIQUE USED	STANDARD METHOD
1.	**pH**	Electrometric method	pH meter	*IS 3025 Part (11), Reaffirmed 2002) APHA 23rd Ed, 4500-H^+ B*
2.	**Electrical Conductivity**	Electrometric method	EH meter	*IS 3025 Part (14), Reaffirmed 2002) APHA 23rd Ed, 2510 B*
3.	**Chloride analysis by Argentometric Titration**	Argentometric method	Titrimetric method	*IS 3025 Part (32), Reaffirmed 2019) APHA 23rd Ed,4500-Cl^-B APHA 23rd Ed, 4110 B and 4110 C*
4.	**Chloride analysis by Ion Chromatography**	Ion Chromatography	Ion Chromatograph	
5.	**Total Hardness Analysis by EDTA method**	EDTA method	Titrimetric method	*IS 3025 Part (21), Reaffirmed 2019) APHA 23rd Ed, 2340C APHA 23rd Ed,3500 Ca B APHA 23rd Ed, 4110 B and 4110 C APHA 23rd Ed,3500 Mg B APHA 23rd Ed, 4110 B and 4110 C*
6.	**Calcium analysis by EDTA titrimetric method**	EDTA method	Titrimetric method	
	Calcium analysis by Ion Chromatography	Ion Chromatographic method	Ion Chromatograph	
7.	**Magnesium analysis by EDTA titrimetric method**	EDTA method	Titrimetric method	
	Magnesium analysis by Ion Chromatograph	Ion Chromatography	Ion Chromatograph	
8.	**Sodium and Potassium analysis by Flame emission photometric method**	Emission spectroscopy/Flame photometry method	Flame Photometer	*IS 3025 Part (45), Reaffirmed 2019) APHA 23rd Ed, 3500 Na-DAPHA 23rd Ed, 3500 K-D APHA 23rd Ed, 4110 B and 4110 C*
	Sodium and Potassium analysis by Ion Chromatography	Ion Chromatography	Ion Chromatograph	

SL. NO.	DETAILS	TECHNIQUE/METHOD	INSTRUMENT/ TECHNIQUE USED	STANDARD METHOD
9.	**Total Alkalinity, Carbonate and Bicarbonate analysis by titrimetry**	Acid-base titration	Titrimetric method	*IS 3025 Part (23):2023 APHA 23rd Ed, 2320 B APHA 23rd Ed,2320 B*
10.	**Turbidity**	Nephelometric method	Nephalo-turbidimeter	*APHA 23rd Ed.*, 2130B
11.	**Iron analysis by Phenanthroline method**	1.10 PHENANTHROLINE METHOD	UV-Visible spectrophotometer	*IS 3025 Part (53), Reaffirmed 2019 APHA 23rd Ed, 3500 Fe B APHA 23rd Ed, 3111 B APHA 23rd Ed,3125 B*
	Iron analysis by AAS method	Flame absorption method	Atomic Absorption spectrophotometer	
	Iron analysis by ICPMS method	Inductively couple plasma spectroscopy	ICPMS	
12.	**Fluoride analysis by Electrometric method**	Electrochemical probe method	Ion meter	*IS 3025 Part (60), Reaffirmed 2019 APHA 23rd Ed, 4500-F^- C APHA 23rd Ed, 4500-F^- D APHA 23rd Ed, 4110 B and 4110 C*
	Fluoride analysis by SPANDS method	SPANDS method	UV-visible	
	Fluoride analysis by Ion Chromatography	Ion Chromatography	Ion Chromatograph	
13.	**Nitrate analysis by Ultraviolet Spectrophotometric Screening Method**	Spectrophotometric Screening Method	UV-visible Spectrophotometer	*IS 3025 Part (34), Reaffirmed 2019 APHA 23rd Ed, 4500-NO_3^- B APHA 23rd Ed, 4110 B and 4110 C*
	Nitrate analysis by Ion Chromatography	Ion Chromatography	Ion Chromatograph	
14.	**Sulfate analysis by Turbidimetric Method**	Turbidimetric Method	UV-visible Spectrophotometer	*IS 3025 Part (24), (Part 24 Sec 1): 2022 APHA 23rd Ed, 4500-SO_4^{2-} E APHA 23rd Ed, 4110 B and 4110 C*
	Sulphate analysis by Ion Chromatography	Ion Chromatography	Ion Chromatograph	
15.	**Arsenic and Selenium Determination by Continuous Hydride Generation/Atomic Absorption Spectrometric Method**	Continuous Hydride Generation	Atomic Absorption spectrophotometer	*IS 3025 (Part 37) : 2022 APHA 23rd Ed, 3114 C*

SL. NO.	DETAILS	TECHNIQUE/METHOD	INSTRUMENT/ TECHNIQUE USED	STANDARD METHOD
16.	**Zinc, Iron, Manganese and Copper Determination by Flame Atomic Absorption Spectrometric Method**	Flame Atomic Absorption Spectrometry	Atomic Absorption spectrophotometer	*APHA 23rd Ed, 3111 B*
17.	**Lead, Chromium, Cadmium, Nickel and Cobalt Determination by Graphite Furnace Atomic Absorption Spectrometric Method**	Graphite Furnace Atomic Absorption Spectrometric Method	Atomic Absorption spectrophotometer	*APHA 23rd Ed, 3113 B*
18.	**Metals By Inductively Coupled Plasma– Mass Spectrometry**	Inductively couple plasma spectroscopy	ICPMS	*APHA 23rd Ed,3125 B*
19.	**Uranium analysis by Fluorometry**	BARC Fluorometric uranium method	Uranium analyzer/Fluorometer	*BARC method, BARC/2014/E/011*
20.	**Uranium by ICPMS**	Inductively couple plasma spectroscopy	ICPMS	*APHA 23rd Ed,3125 B*

5. Data Quality Control

Groundwater quality data validation is an essential step in ensuring the reliability and accuracy of the data. Detail QC & QA as per ISO/IEC 17025:2017 protocol for accreditation of Water testing Lab by NABL are illustrated in ***Annexure II to VII and Ground Water Quality Data Analysis Report.***

One of the mandatory steps to follow is as follows

Charge Balance Error

$$\%\text{balance error} = \frac{\Sigma\text{cat ions} - \Sigma\text{anions}}{\Sigma\text{cat ions} + \Sigma\text{anions}} * 100$$

Error ± 5% for GW & SW
Not applicable for very concentrated and very dilute solutions

TDS (mg/l) ~ (0.65) x EC (µS/cm)
For Freshwater

- **It is recommended to take the value of constant as 0.65 in all regions for maintaining uniformity of data.**
- **ECB of 2% is inevitable in almost all laboratories. ECB%≤ 5% for groundwater but not applicable for very concentrated and very dilute solutions. ECB may go upto 10% for very low and very high concentrations.**
- **Flag Data: Flag any data that does not meet the quality control criteria and document the reason for flagging. The sample should be re-sampled/re-analysed to ensure the accuracy and validation of data.**

6. Pre-processing of Data

Convert the ground water quality data into a suitable format for analysis which is illustrated in Table 6. The same format will used to share data with Central Pollution Control Board (CPCB).

Table 6. Format for Water quality data sharing (Common excel format CGWB-CPCB)

Details of Ground Water Quality Monitoring Station																	
S. No.	Agency Name	Well No	State/UT	District	Block/ Taluk	GP	Village	Station Name/ Location	Details of Location	Longitude (DD)	Latitude (DD)	Basin	Sub-Basin	Sample Source	Use	Depth of Sample	Sampling Date
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

Physical Parameters		Chemical Parameters																
		Basic Parameters																
Temp (° C)	Turbidity (NTU)	pH	EC (µS/cm at 25° C)	TDS (mg/L)	CO_3 (mg/L)	HCO_3 (mg/L)	Total Alkalinity (mg/L)	Cl (mg/L)	NO_3 (mg/L)	SO_4 (mg/L)	PO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	TH (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37

Chemical Parameters									
Heavy Metals									
Fe (mg/L)	As (mg/L)	U (mg/L)	Mn (mg/L)	Cu (mg/L)	Pb (mg/L)	Zn (mg/L)	Ni (mg/L)	Cd (mg/L)	Cr (mg/L)
38	39	40	41	42	43	44	45	46	47

Biological Parameters				
BOD (mg/L)	COD (mg/L)	TOC (mg/L)	Faecal Coliform (MPN/100ml)	Total Coliform (MPN/100ml)
48	49	50	51	52

Checking of Coordinates: Geographical coordinates of a station must lie within the country boundary.

7. Data Analysis, Interpretation and Reporting

The specific groundwater data analyses are to be conducted depending on the water quality information desired or the specific questions about water quality being asked. Water quality concerns are wide and varied, but probably the most commonly asked questions are:

The Laboratory should make sure that the data analysis and interpretation performed by it is able to answer these questions clearly for effective management plans.

1. What is the water quality at any specific location or area?
2. What are the water quality trends in the region? Is the quality improving or getting worse?
3. How do specific water quality parameters relate with one another at given sites?
4. What are the total mass loadings of materials moving in and out of water systems and what sources and quantities do these originate?
5. Are sampling frequencies adequate, and are sampling stations suitably located to represent water quality conditions in an area?

7.1 Groundwater quality data analysis for Technical Reports

7.1.1 Data interpretation for drinking purposes

Comparing the data with national water quality standards - gives an insight into the scale of a particular data set (e.g., if the data show that a specific groundwater sample contains a higher concentration of pollutant than is allowed by a national drinking water standard -BIS drinking water specification, most people would assume that it may not be safe to drink this water).

(a) Statistical analysis

Analyze the data using appropriate statistical methods and tools such as descriptive statistics such as mean, median, mode, standard deviation, and range to describe the data set. Interpret the results to determine whether groundwater quality is within acceptable limits/permissible limits per BIS standards. If not, identify areas of concern and potential sources of contamination in consultation with field officers and by examining field conditions. Groundwater quality data comparing with national and international standards as illustrated in *Figure 3 (Dutta et al., 2022) of GWQDA-Report may be referred.* An example of Statistical analysis is given below.

Paramters	Unit	Post-Monsoon				Pre-Monsoon				Prescribed limits	
		Min	Mean	Max	SD	Min	Mean	Max	SD	BIS	WHO

(b) Graphical analysis

Graphical representation of Ground Water Quality data is listed below:

(i) Spatial Analysis

This type of analysis is essential because it helps to identify areas that may be at higher risk of contamination, as well as the sources and causes of contamination. Geographical Information System (GIS) tools may be used to map and visualize the distribution of various parameters geographically. Some examples of graphs showing Spatial analysis could be referred from *Datta et al., (2021); Barman et al., (2022); Figure* 4.**(GWQDA-Report).**

- **Contour map should be prepared for EC and Cl.**
- **Point map for As, F, U, Cd, etc.**

(ii) Trends Analysis

The **trend analysis for 5 or 10 years period using district or block-wise water quality data** is to be carried out and included in the water quality report. More than 10 year long- term trend analysis can be done subjected to availability of suitable data. Based on trend analysis, the reasons for ground water contamination may be assessed and shared with authorities for corrective action and adjustment of management strategies accordingly. Some examples of graphs showing trends analysis could be referred from the examples below.

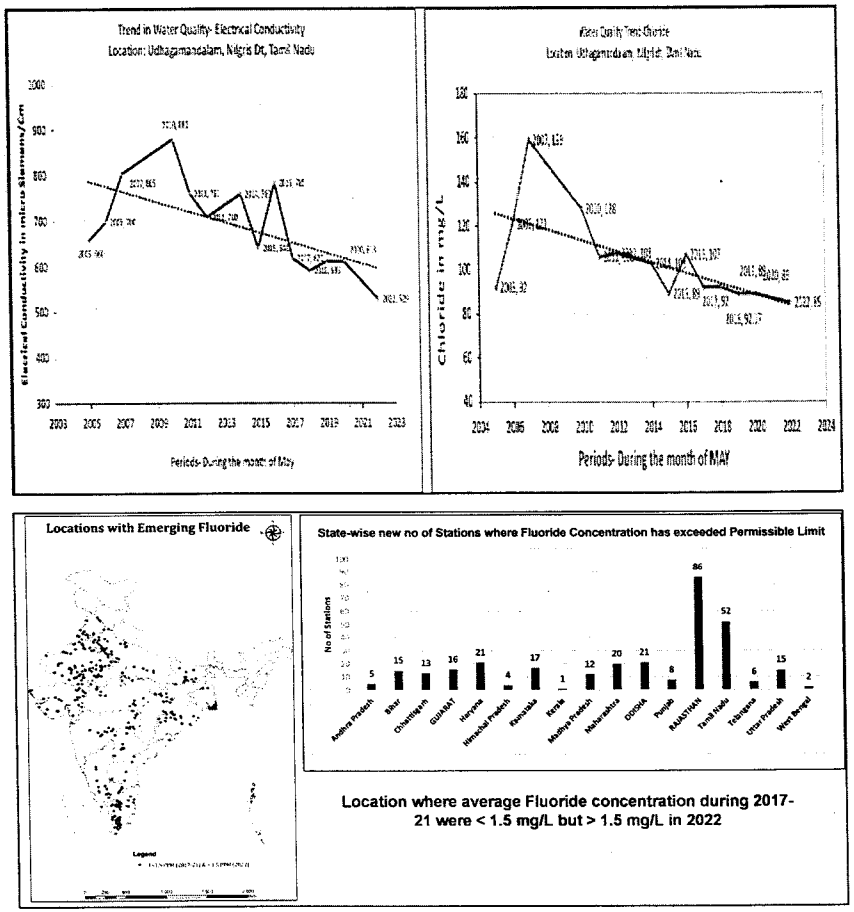


Figure 2. (Up) Figure showing time series analysis for Electrical Conductivity and Chloride at Udhagamandalam, Nilgiris Dt, Tamil Nadu; (Down) trends analysis of Fluoride distribution

Year	Total Number of samples analysed	No. of districts affected by Fluoride	No. of locations affected by Fluoride	% of locations affected by Fluoride (F >1.5mg/l)
2017	13225	207	736	**5.57**
2018	13229	212	862	**6.52**
2019	12475	226	899	**7.21**
2020	6366	131	449	**7.05**
2021	8482	142	450	**5.31**
2022	15507	**392**	**1048**	**6.76**

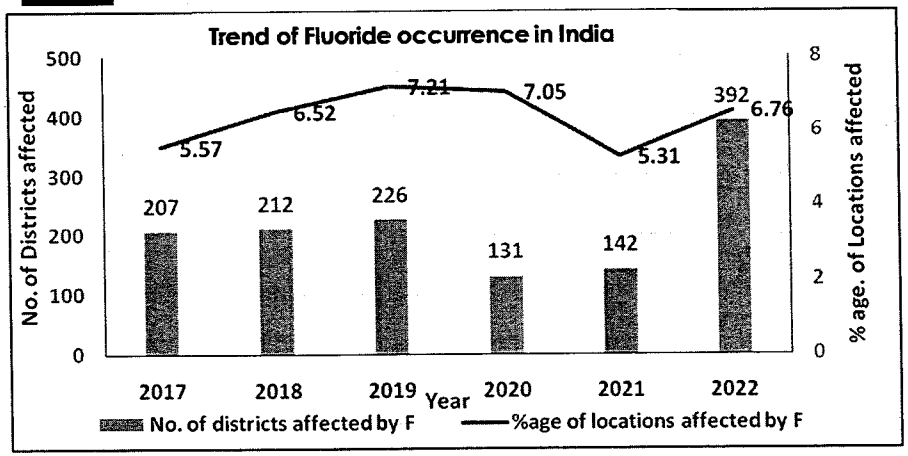


Figure 3. Example of Table and figure showing trend analysis of Fluoride of India

7.1.2 Data interpretation for irrigation purposes

Suitability of ground water for irrigation purpose is evaluated based on chemical characteristics indicative of their potential to create soil condition hazardous to crop growth and yield. Various indices are used for assessment and classification of ground water into different categories. Some of the widely used criteria are discussed below. The data obtained from various indices can be illustrated in ***Table 7 of GWQDA-Report.***

(a) U S Salinity diagram

U S Salinity diagram (Figure 4) can be used to quickly determine the viability of water for irrigation purposes. For detail explanation refers **GWQDA-Report**.

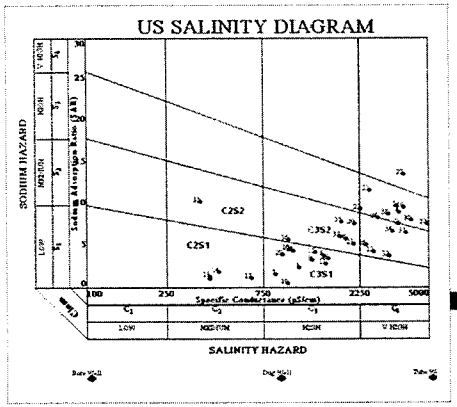


Figure showing US Salinity Diagram

Degree	Quality	Class	State of use
1	Excellent	C1-S1	Safe use for irrigation of most crops on most soils.
		C1-S2	
2	Good	C2-S1	Suitable for plants that have tolerance to salts, however its use can cause problems for clays.
		C2-S2	
3	Acceptable	C3-S1	Salinity must be controlled, irrigation of tolerable crops to salts on well-drained soils.
		C2-S3	
		C3-S2	
4	Poor	C4-S1	Highly mineralized water, used only for very salt-resistant plants with good soil permeability.
		C4-S2	
		C3-S3	
5	Bad	C3-S4	Unusable
		C4-S3	
		C4-S4	

Classification of waters based on U.S Salinity diagram and percent of samples falling in each category.

Salinity hazard (Electrical Conductivity in µS/cm at 25 °C)

Sodium Hazards Sodium Absorption Ratio (SAR)		C1 Low 250	C2 Medium 251-750	C3 High 751-2250	C4 Very high >2250
	S1 Low (< 10)	2.9 %	8.8 4%	29.4 %	--
	S2 Medium (11-18)	--	2.9 %	17.6 %	14.7 %
	S3 High (19-26)	--	--	--	23.5 %
	S4 Very High (> 26)	--	--	--	2.9 %

Several water quality indices should be calculated which indicate the suitability of water for different uses

a. *Percent* sodium Absorption Ration (SAR)
b. Percent Sodium for irrigation suitability
c. Kelly's index (KI)
d. Residual Sodium Carbonate – for irrigation suitability
e. Chloride – bicarbonate ratio

Figure 4: Figure showing U S Salinity diagram

(b) Wilcox Plot

Wilcox classified groundwater for irrigation purposes based on percent sodium and EC. For detail explanation refers **GWQDA-Report**. The water quality data of a well for the period of 1992 to 2006 was plotted on Wilcox plot for the classification of groundwater samples with respect to percent sodium and EC is shown in Figure 10.

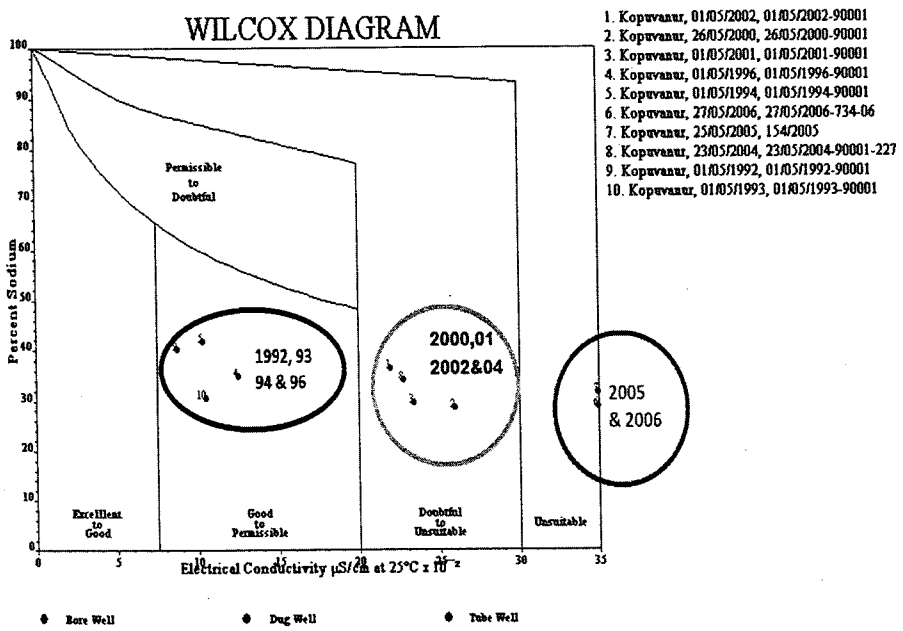


Figure 5. Figure showing classification of groundwater with respect to percent sodium and EC (Wilcox Diagram)

Table 7. Showing Classification of ground water samples for irrigation purposes.

Parameters	Range	Classification	Number of samples Pre-Monsoon	Post -monsoon
Total Dissolved Solid (TDS) (mg/L)	<1000	Non-saline	600	599
	1000-3000	Slightly saline	2	2
	3000-10000	Moderately saline	0	0
	>10000	Very saline	0	1
Salinity hazard (EC) (µS/cm)	<250	Excellent	279	394
	250-750	Good	267	184
	750-2000	Permissible	54	22
	2000-3000	Doubtful	0	1
	>3000	Unsuitable	0	0
Alkalinity hazard (SAR)	<10	Excellent	602	598
	10--18	Good	0	1
	18-26	Doubtful	0	1
	>26	Unsuitable	0	2
Percent Sodium (%Na)	<20	Excellent	98	338
	20-40	Good	240	149
	40-60	Permissible	185	88
	60-80	Doubtful	76	22
	>80	Unsuitable	3	5
Kelly's Index (KI)	<1	Suitable	467	564
	>1	Unsuitable	135	38
Residual sodium carbonate (RSC)	<1.25	Suitable	539	566
	1.25-2.5	Marginally suitable	37	22
	>2.5	Unsuitable	26	14

7.1.3. Groundwater quality data analysis for Hydrogeological Processes

(a) Piper diagram

A trilinear diagram, Piper or Hill diagram, is used for identifying facies, as shown in Figure 6. The position of analysis of a water sample placed on a Piper plot can help reach a tentative conclusion as to the origin of groundwater. Piper plots can help us understand water type, precipitation, mixing and ion

exchange in aquifer geochemistry. For detail explanation refers **GWQDA-Report**. Figure 6 shows the Piper plot of a groundwater sample from Vridachalam, Tamil Nadu, where the Water quality data of a well from 1986 to 2008 is plotted.

(b) Chadha Diagram

Another approach to investigating Groundwater facies assessment was introduced in the form of a modified Piper Diagram by D.K. Chadha, the former Chairman of CGWB (Chadha et al. in 1999). It's a simplified adaptation of the original Piper plot. The hydrogeochemical facies classification is then derived from the information presented in the Chadha diagram (Figure 7). *Refers **GWQDA-Report** for illustrated explanation.*

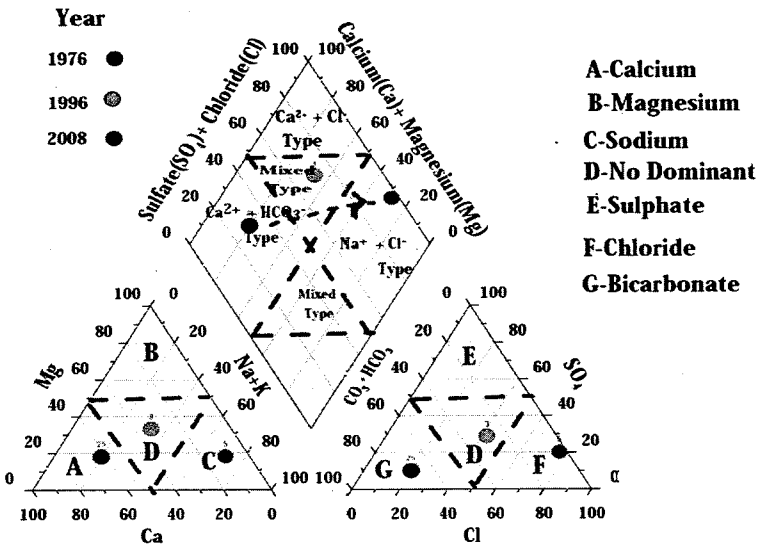


Figure 6. Figure showing a trilinear diagram known as Piper or Hill diagram.

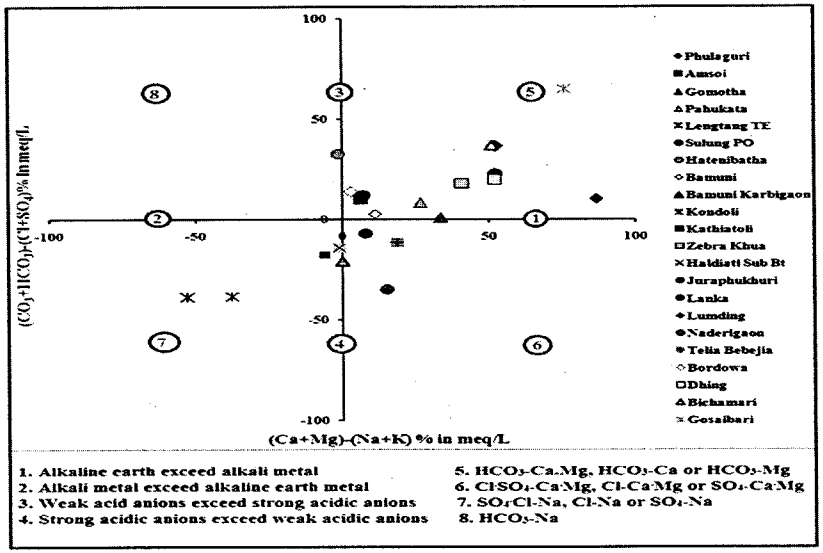


Figure 7. Figure showing Chadha Diagram (Barman et al., 2022)

(c) Schoeller diagram

Schoeller diagrams are used to show the relative concentrations of anions and cations typically expressed in milliequivalents per litre. Multiple samples from different wells may be plotted on a single diagram to distinguish similar patterns in the ratios of particular anions and cations. These patterns may be used to distinguish common or dissimilar source areas of water drawn from multiple wells. Figure 8 shows that shallow aquifer wells have different nitrate concentrations. For the same study area, nitrate concentration for the deeper aquifer is close to zero except for one well, which indicates that the deeper aquifer is not affected by nitrate. Still, the shallow aquifer is affected by nitrate due to anthropogenic activities

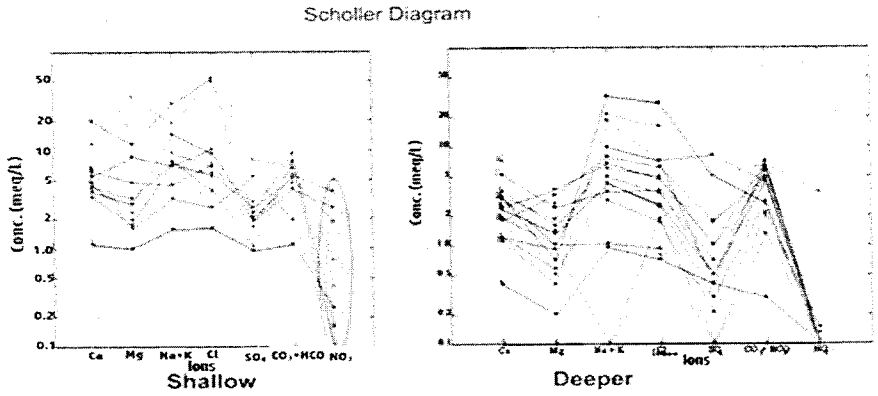


Figure 8: Relative concentrations of anions and cations in milliequivalents per liter for different aquifers of same area.

(d) Gibb's Plot

To further understand the hydrogeochemical procedures with reverence to atmospheric precipitation, rock–water interaction, and evaporation over the administration of geochemistry of groundwater, two diagrams called as 'Gibbs Plot' was introduced by R. J. Gibbs in 1970. In these plots the ratios for cations and anions are plotted against relative values of TDS for the groundwater samples. The relative clustering of the samples on the plot suggests dominance of evaporation or rock-water interaction phenomena. It also gives a clear idea about the influence of anthropogenic activities (like agricultural fertilizers, canal/river water mixing, etc.) on groundwater quality. A detailed explanation is explained in GWQDA-Report.

7.1.4 Water Quality Assessment

Water Quality Indices (WQI)

Water Quality Index (WQI) is a metric used to assess the overall quality of water based on multiple parameters. When analyzing groundwater quality data using WQI, the following steps are typically involved. Various WQI developed for surface water and other forms of water. However, no specific WQI

developed for Ground water free from demerits. In this regard, a new WQI based on regional hydro-geological conditions may be a good option. Howbeit, weighted arithmetic WQI and CCME WQI can be employed for basic assessment and indexing. Example of weighted arithmetic WQI for assessment of ground water *(Datta et al., 2023; (Dutta et al., 2022)* **has been explained in GWQDA-Report.**

8. Data Compilation and Sharing

To ensure accurate and accessible information, compiling and sharing groundwater quality data is very crucial. The Ground Water Quality Analysis Report will be the annual compilation of ground water quality data of CGWB, which will be prepared on water year basis.

8.2 Data Compiling

Data reporting is necessary to ensure consistency in units, formatting, and data structures across different datasets. It may involve converting measurements to a standard unit system and standardizing data formats (e.g., CSV, Excel), e.g. Table 8 **(Annexure viii).**

8.2 Data Sharing

Once contamination of groundwater for any parameter is detected in any of the monitoring well (National level monitoring/Special purpose monitoring/Special studies) the following approach is to be adopted.

(a) In the form of a Report

The reports on State/UT or pan-India basis should be published in the month of September every year for the previous water year.

(b) Online publication in CGWB web portal, India-WRIS portal (NWIC) etc.

As per the directives from Ministry a common data format has been prepared for CGWB and CPCB for sharing and integration of ground water quality data as
shown in Table 6.

(c) Sharing with Stakeholders

This step involves sharing the compiled data with relevant stakeholders, such as local government agencies (PHED, JJM, WRD, DoDW&S etc.), water management organizations, researchers, and environmental NGOs. The report may be shared with District/State/UT administrations.

Sharing of Water Quality Report / Data

Report/ Data Sharing	Frequency (on water year basis)	Remarks
Pan-India Groundwater Quality Data / Report	September every year (for previous water year)	In Public domain
Trend analysis for 5-year and 10-year Quality data	September every year (for previous water year)	To be shared with Authorities for corrective action.
GW Quality Report	September every year (for previous water year)	In Public domain

The groundwater quality reports shall be shared with States/UTs, DoDW&S, and a copy shall be marked to the district administration.

The details of data collection points along with co-ordinates and utilization of the source is to be mentioned in the report.

Repeat sampling is to be done from the site where contaminants exceed BIS permissible limit.

Any information regarding groundwater contamination shall be brought into the public domain through the CGWB website and NWIC.

Annexures

Annexure I: Collection and preservation of ground water sample
Annexure II: SOP for water analysis
Annexure III: Laboratory Procedure Manual
Annexure IV: Work Instructions
Annexure V: Quality Manual
Annexure VI: Format
Annexure VII: Measurement of Uncertainty
Annexure VIII: Excel sheet as per CHQ format (Standard format for reporting)
Annexure IX: Format for water quality data sharing (Common Excel format for CGWB-CPCB)

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