ISOTOPE HYDROCHEMISTRY AS ENVIRONMENTAL HEALTH FINGERPRINTS OF POLLUTION IN MINING-METALLURGICAL COMPLEX OF SUBARNAREKHA BASIN, GHATSHILA, JHARKHAND, INDIA

Abstract

The Singhbhum region of Jharkhand is a geologically significant mineralized zone having long history of mining and beneficiation of strategic minerals namely copper and uranium [1]. Back then, the mining and mineral processing wastes have grossly polluted the water courses in associated Subarnarekha basin. The understanding of recharge mechanism and hydrogeological dynamics of this mining-smelter affected watershed is important for protection and sustainable water management system. Subsurface water primarily exists in unconfined and confined conditions and moves slowly through hydraulically significant fracture zones. The Subarnarekha is the principal pollution recipient of mining and industrial discharges, also acts as the lifeline of water supply to nearby towns and urban/rural hamlets. But no notable research exists in literature that sheds light on exact source, pattern and pathways of surface/sub-surface pollution conduits in this mine impacted river basin [2].

Keywords: Fingerprints, hydrochemistry, isotopes, mining, pollution, Subarnarekha

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I. STUDY OBJECTIVE

The study seeks to apply the marvels of environmental stable isotopes and major ion hydrochemistry as twin tracers and fingerprinting of pollution in Subarnarekha river basin, with the aim of evaluating the impacts of metalliferous mining and ore processing onto the hydrogeological system.

II. STUDY AREA

The present study was carried out in the Ghatsila region of East Singhbhum district, Jharkhand for a longitudinal section of 30 km and lateral stretch of 5 km on either banks of Subarnarekha River. Hydro-chemical and isotope monitoring was essentially focused in and around Mosabani-Surda-Rakha copper mines/smelter units of Mosabani and Moubhandar, and Jaduguda uranium mine (Figs. 1 and 2).

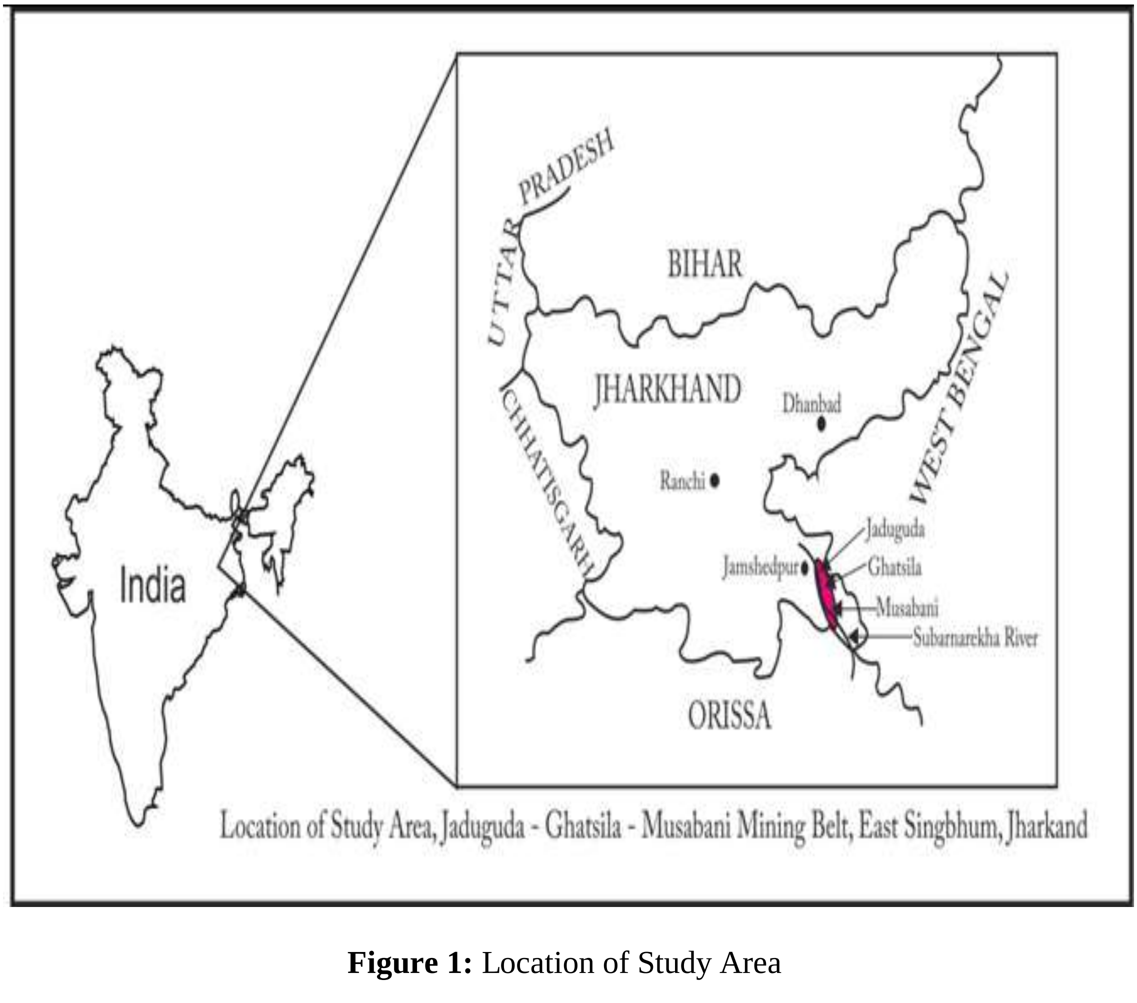


Figure 1: Location of Study Area

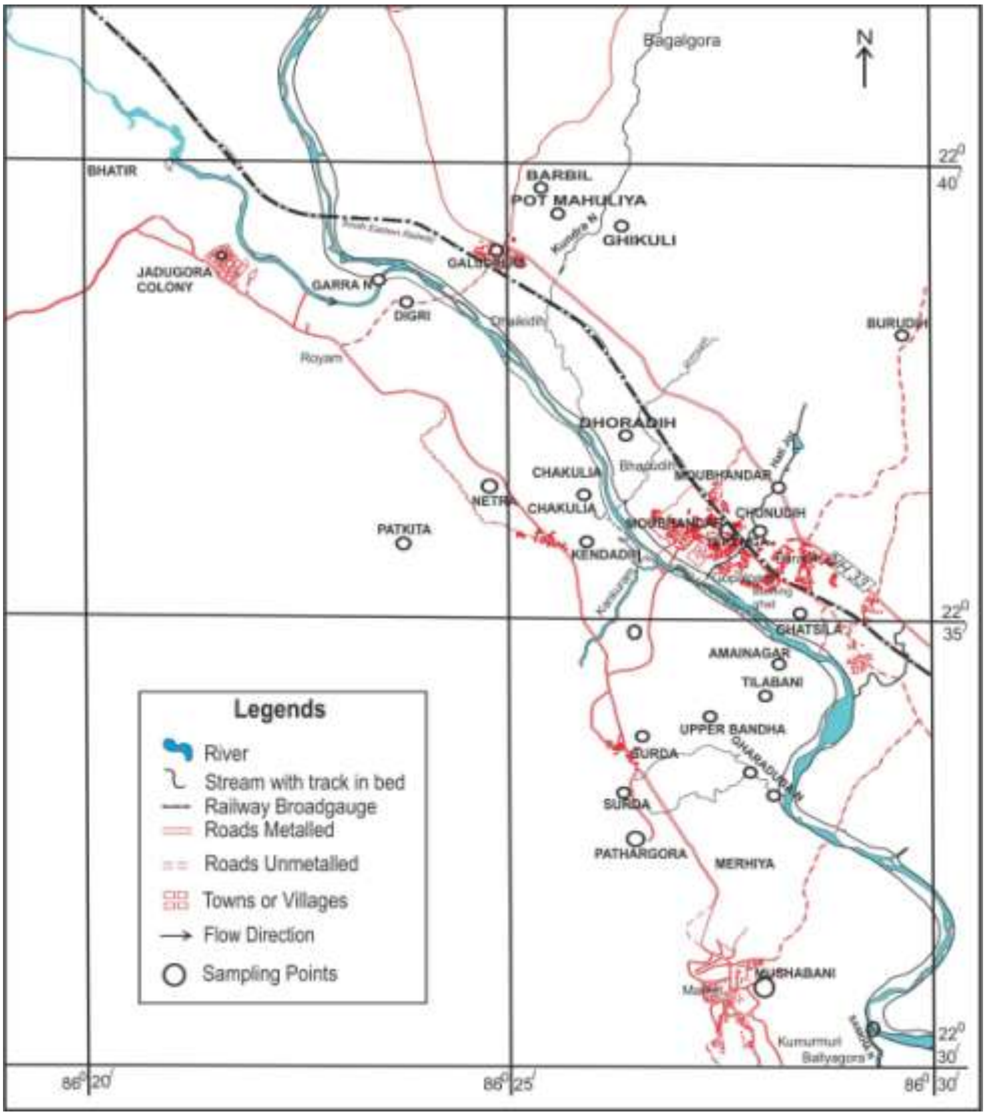


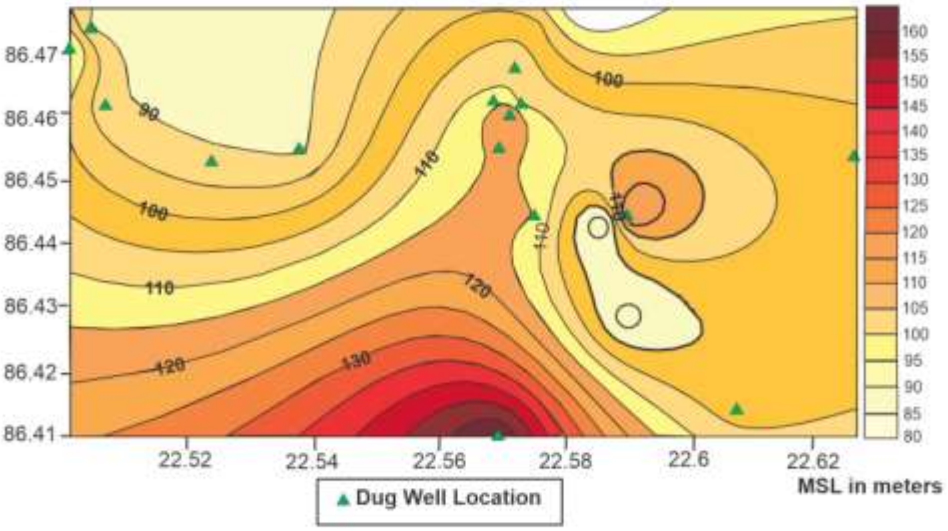
Figure 2: Subarnarekha River in Study Area with Sampling Points

III. RESULTS

The groundwater flow conditions were observed through an inventoried network of 54 hydrograph stations (Fig.3). The dominant groundwater flow was found to exist towards Subarnarekha and there are distinctive locales of groundwater-river water interaction on both banks of Subarnarekha.Hydrogeological monitoring proves that Subarnarekha acts both as an effluent and influent river. The river serves as an important pollution sink for captive mines in hot lean dry weather flow and substantially adds to pollution of neighbourhood aquifers when it is at spate in the monsoons.

Water Level Altitude Map

(a) Pre monsoon



(b) Post monsoon

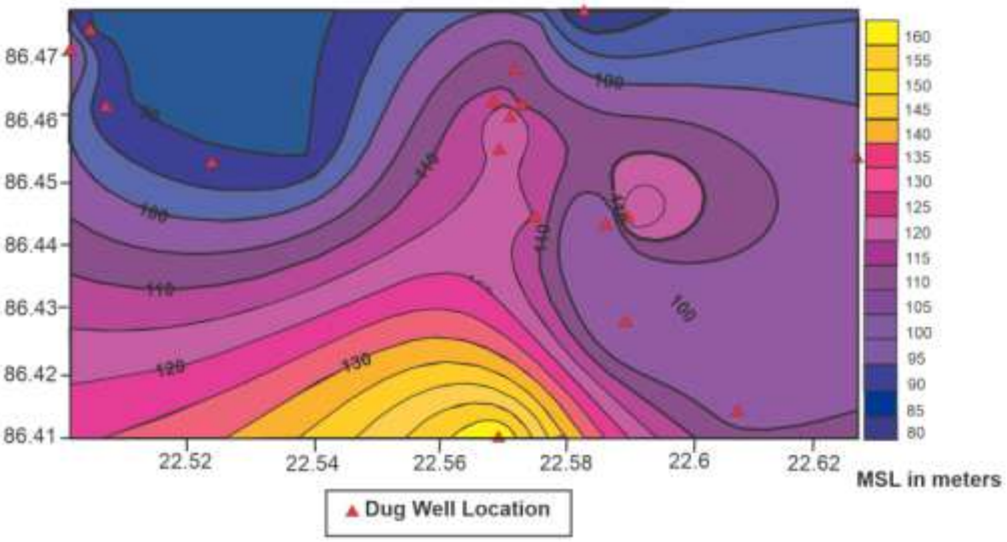


Figure 3: Groundwater Contour Map of Study Area Showing Dominant Flow Directions

IV. DRINKING WATER QUALITY

54 water samples collected from various sources (Table 1) were analyzed for physico-chemical parameters namely temperature, TDS, alkalinity, hardness, calcium, magnesium, sodium, potassium, chloride, sulphate, nitrate, and fluoride. The compliance of water quality to drinking water standards is given in Table 2.

From the results (Table 2), it is found that 43% of the samples (mostly groundwater) are acidic in nature and 13% (dominantly Subarnarekha river samples) fall in alkaline range. Majority of the analyzed parameters are observed to lie above the desirable limits.

Table 1: Classification of Water Sources

Surface Water					**Groundwater**				Total Number of Collected Samples
River	Pond	Reservoir	Nala	Total	Tube Well	Dug Well	Spring Water	Total	
8	4	3	9	24	17	11	2	30	54

V. HEAVY METAL QUALITY: (TABLE 2)

Iron is excess than desirable limit in all the analyzed samples. After iron, comes nickel which is higher in 72% of samples, followed by arsenic (33%), copper (27%), manganese (22%) and cadmium (11%), as stipulated limit by Bureau of Indian Standards (BIS) [3] and World Health Organization (WHO) [4].

Table 2: Compliance of Water Quality to Drinking Water Standards

Parameters	**Specifications as per BIS 10500 : 2012**	**Specifications as per WHO: 2011**	**Unit of Concentration**	**Range of Concentration Noted**	**Samples Exceeding Desirable / Permissible Limits**
	Limit Range (In Absence of Alternative Sources)				
Routine Parameter Analyses (Total Number of Samples = 54)					
pH	6.5 -8.5	6.5 – 8.5	-	3.27 – 10.2	30 / 7
Conductivity	750-3000	400	µs/cm	196 – 2290	19 / 0
TDS	500-2000	500	mg/L	65.65 – 41015	20 / 2
Alkalinity	200-600	500		28 – 590	20 / 2
Hardness	200-600	500		80 – 1400	41 / 3
Calcium	75-200	75		8 – 352	29 / 2
Magnesium	30-100	30		2.92 – 208.1	24 / 2
Sodium	200	200		10 – 23.5	54 / 0
Potassium	3000	12		0.05 – 4.2	0 / 0
Chloride	250-1000	200		39.49 – 309.89	4 / 0
Sulphate	200-400	250		33.09 – 376.16	4 / 0
Nitrate	45	45		2.92 – 208.1	0 / 0
Fluoride	1-1.5	1.5		0.01– 2.62	11/ 2
Heavy Metal Analyses (Total Number of Samples = 18)					
Manganese	0.1-0.3	0.1	mg/L	0.14 – 0.67	10 / 4
Arsenic	0.010.05	0.01		0.3 – 3.5	6 / 6
Iron	0.3-3.5	0.3		0.61 – 42.37	18 /18
Copper	0.05-1.5	2		0.19 – 5.80	8 / 5
Lead	0.01	0.01		-	0 / 0
Zinc	5 -15	0.1		0.19 – 3.23	0 / 0
Cadmium	0.003	0.003		-	2 / 2
Mercury	0.001	0.006		-	0 / 0
Chromium(T)	0.05	0.05		-	1 / 1
Nickel	0.02	0.07		0.12 – 6.02	13 / 13

VI. ISOTOPIC ANALYSIS

The results of isotopic analyses show that $\delta^{18}O$ and $\delta^{2}H$ respectively varies from -6.3% to -2.7 % and -42.4 % to -14.8% for groundwater, and from -5.2% to -1.9% and -35.3% to -15.3% for surface water. Generally, samples with depleted $\delta^{18}O$ have lower TDS content samples, while samples having enriched $\delta^{18}O$ have higher TDS. This shows enhancement of TDS in majority of samples is due to evaporation, some of the samples are depleted in isotopic composition yet higher in TDS, which indicate influence of Acid Mine Drainage (AMD) [5].

Majority of groundwater samples are falling on Global Meteoric Water Line (GMWL), indicating recharge from rainwater (Fig. 4A). On other hand, surface water samples dominantly fall away from GMWL that indicate enrichment due to evaporation. Some groundwater show exception and indicate recharge and interaction with surface water. Stable isotopic composition of pond water is highly enriched while that of nala and river water is moderately enriched.

Increased EC in samples indicates intensive rock-water interaction or influence of AMD. Few groundwater samples have higher EC and isotopically identical with nala water and connectivity thereof (Fig. 4B)

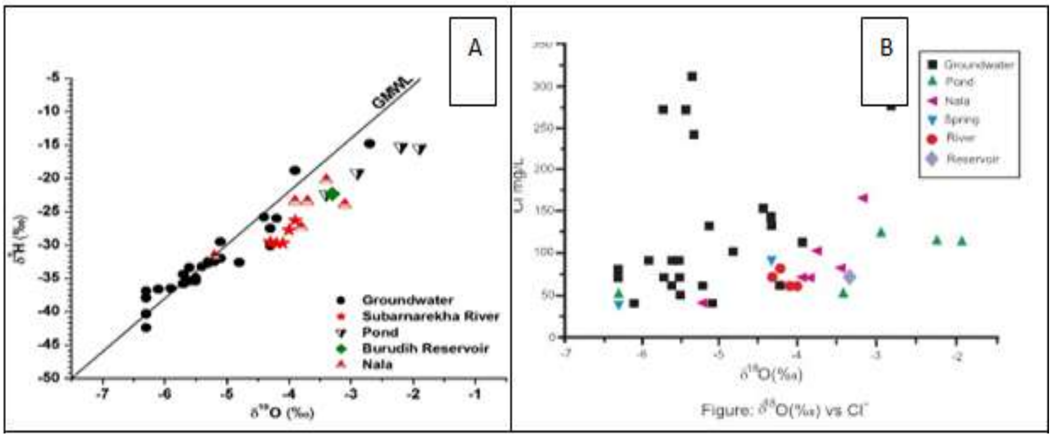


Figure 4: A. $\delta^{18}O$ vs$\delta^{2}H$ Plots of Water Samples; B. EC vs$\delta^{18}O$ Plots for Water Samples

VII. INDUSTRIAL WATER QUALITY

Anon [6] had suggested the water quality criteria for assessment of incrustation and corrosion properties of water which are harmful to industrial sector (Tables 3). If water shows>400 mg/L of HCO_3^- or 100 mg/L of SO_4^{2-}, it causes incrustation, and if water has pH< 7 or TDS>1000 mg/L or Cl>500 mg/L, it causes corrosion.

Table 3: Interpretation of Corrosion Indices (Anon, 1986)

Sl No.	Description	Interpretation	No. of Ground Water Sample	No. of Surface Water Sample
1.	Ryznar Stability Index (RSI)	< 6 – Super saturated tend to ppt. $CaCO_3$	0	2
		6<I<7 – Saturated $CaCO_3$ is in equilibrium	4	7
		>7 – Under saturated, tend to dissolve solid $CaCO_3$	26	15
2.	Puckorius Scaling (PSI)	< 6 - Scaling is unlikely to occur	15	6
		> 7 Likely to dissolve scale	9	15
3.	Langelier Saturation Index (LSI)	>0 – Super saturated tend to ppt. $CaCO_3$	21	12
		= 0 – Saturated $CaCO_3$ is in equilibrium	1	0
		< 0 – Under saturated, tend to dissolve solid $CaCO_3$	8	12
4.	Aggressive Index (AI)	> 12 –Non aggressive	8	13
		10 <I < 12 – Moderately aggressive	22	8
		< 10 – Very aggressive	0	3
5.	Larson – Skold Index (LS)	< 0.8 – Chloride and sulphate are likely to interfere with the formation of protected film	13	1
		0.8 <I < 1.2 – Corrosion rates may be higher than expected	14	12
		> 1.2 – High rates of localized corrosion may expected	3	11
6.	Corrosivity Ratio (CR)	< 1 is considered to be safe for transport of water in any type of pipes,	19	5
		>1 indicate corrosive nature and hence not to be transported through metal pipes	11	19

VIII. AGRICULTURAL WATER QUALITY

Multivariate statistical analyses were performed to obtain significant information from hydrogeo-chemical characteristics of the collected samples. Chemical variables were graphically interpreted using US Salinity diagram after Richards [7], Wilcox [8], Gibbs [9] and Piper [10] to show the facies of study area (Figs. 5 to 8). In US Salinity diagram, all the samples fall in C1-S1 facies. In Wilcox diagram, majority of samples fall in 'Good to Permissible' category, although appreciable samples are there under the 'Doubtful to

Unsuitable' class also. In Gibbs diagram, the samples are governed by rock dominance. The Piper trilinear plots indicate the most of the waters belong to Ca-Mg-SO_4-Cl hydrochemical facies with minor samples falling under the Na-K-SO_4-Cl facies type.

IX. IN PURSUIT OF GREEN WATER ECONOMICS

The Sustainable Development Goals (SDGs) of United Nations (2015) share the master blueprint for a good sustainable future ahead for the Earth and the Earthlings. Their adoption has put the issues of environmental degradation, sustainability, climate change, and water security in the realm of international beacon, intended to be achieved globally by the year 2030. The Millennium Development Goals aim to leave no water user unmarked, that stand vital in achieving the CDP's (Committee for Development Policy) vision for a thriving economy for the people and the planet.

Investments in water is a good business – improved water resources management and improved water supply and sanitation contributes significantly to increased production and productivity within economic sectors. Investments in managing water resources are going to be increasingly needed in the context of increasing water scarcity at the local, regional and global levels. The triple bottom line framework provides the tool for decision-makers to evaluate water infrastructure investments based on economic, social and environmental goals. In this way, infrastructure investments may be optimized without compromising the core purpose of the infrastructure asset. Corporate action will be crucial in delivering the 2030 Agenda, and disclosing to CDP companies can contribute towards the SDGs.

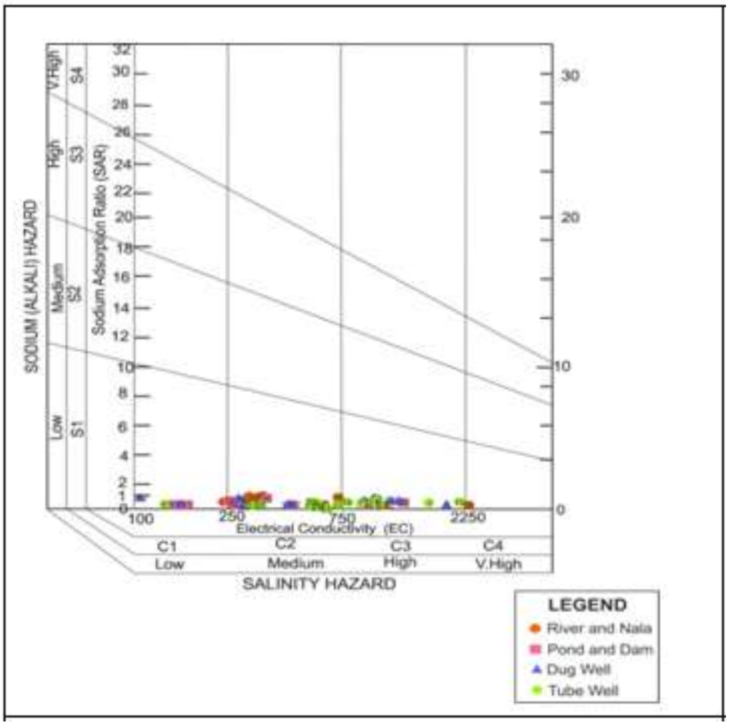


Figure 5: Classification of Groundwater Quality for Irrigation (after Richards, 1954).

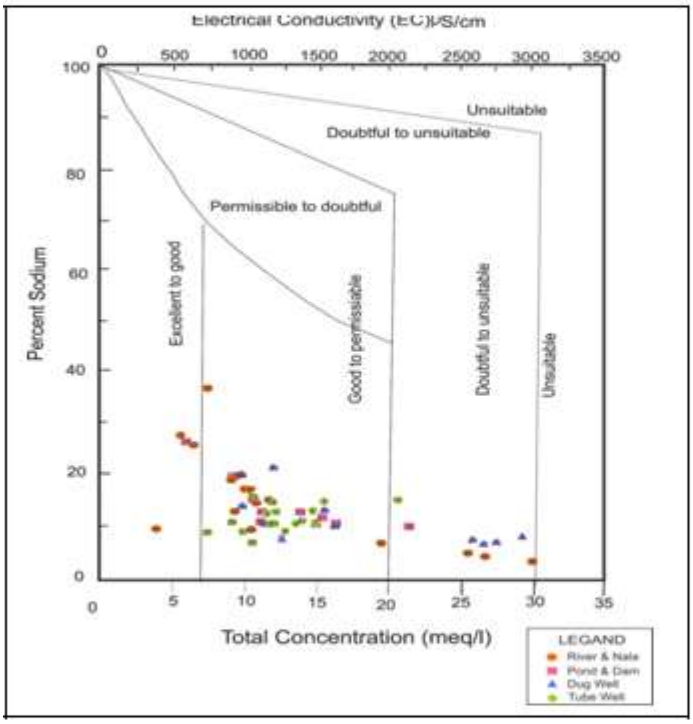


Figure 6: Classification of Groundwater Quality for Irrigation (after Wilcox, 1954).

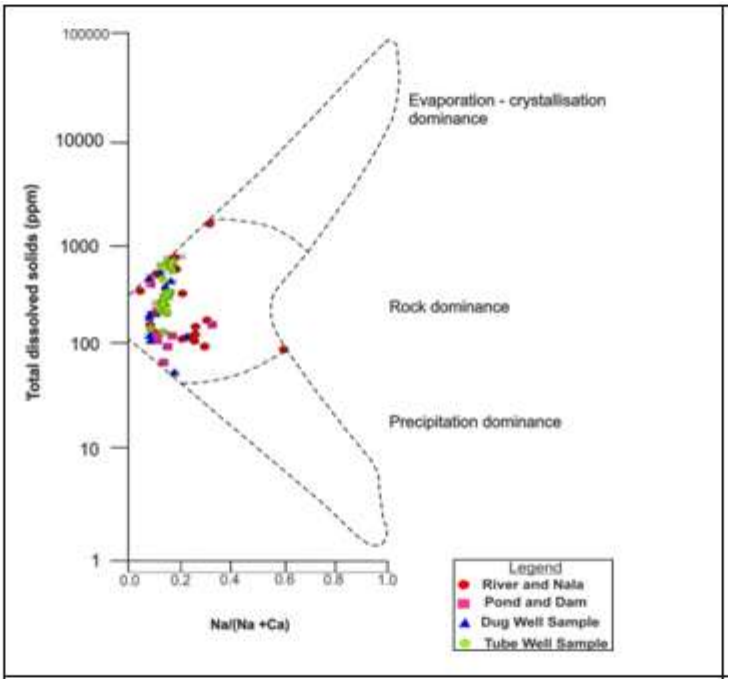


Figure 7: Classification of Groundwater Quality for Irrigation (after Gibbs, 1970).

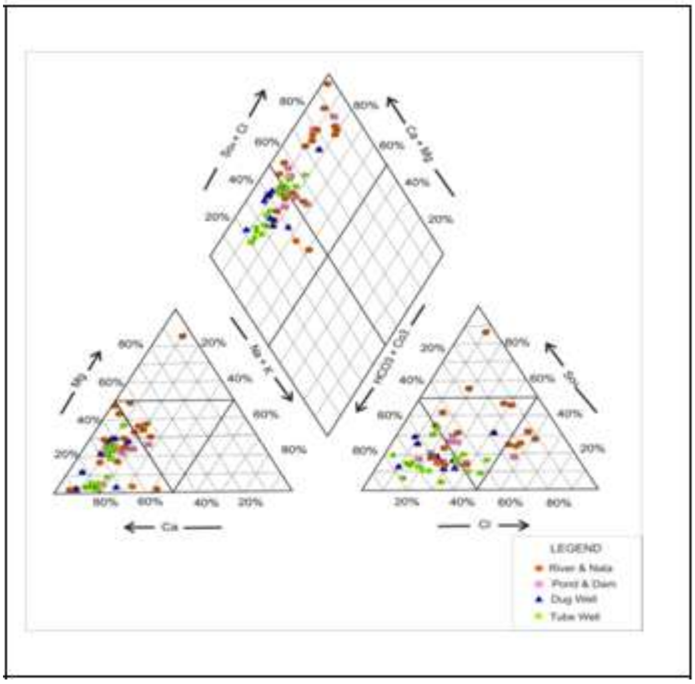


Figure 8: Classification of Groundwater Quality for Irrigation (after Piper, 1944).

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