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Case study

Impacts of mining on groundwater environment near Khetri mine, Rajasthan (India): A Case study

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Abstract

The present discourses emphasize that mining is an essential evil for economy of any country, but adversely affects the environment (air, soil, water, vegetation and human beings). Groundwater is the major source of fresh water in many countries and is widely used for domestic, agricultural and industrial purposes). It is a renewable resource with inherent advantages over the surface water for pureness, lesser evaporation and wider distribution. The geochemistry and quality of groundwater is controlled by several processes, such as geology of the area, degree and rate of weathering of parent rock types, rock-water interaction during recharge of aquifer, and rate of groundwater flow of the present study area.

Keywords: Mining, Geology, Groundwater, Copper plant, Reserves.

Introduction

The Khetri Copper Complex (KCC) located at Khetri Nagar (Neem Ka Thana district), north eastern part of the Rajasthan (India) is famous for Cu mining since historical times[1]. The geology of the region is first reported by the Hackett in 1877. The mining ceased by the Britisher's in 1872. In recent decades, the mining is resumed by the Hindustan Copper Limited (HCL) in 1967. Along with Cu extraction unit the smelting and fertilizer plants were also installed at the KCC[2].

The fertilizer plant was established to use the sulphur emitted from the smelter plant for the preparation of fertilizers. Mining for Cu at Khetri, Rajasthan is going since historical times but no systemic and detailed study on distribution and behaviour of heavy metals in various compartments of the environment were carried out[3].

The fine particles of tailings could easily be carried to the distant places by wind and contaminate the surrounding soils. As per the literature, no systematic study has been carried out to understand the abundance and distribution of heavy metals in the tailings and soils of the region with respect to assessed Pollution Load Index[4].

The Khetri region is also known for high rate of depletion of groundwater. This results in increase in EC and TDS, and increased infertility of land/soil. Despite, such information groundwater has been sparsely monitored in and around Khetri copper mining region and little knowledge exists about the quality of groundwater and the related hydro geochemical processes which are important to assess the various impacts[5].

Objectives: i. Geochemical characterisation of mine tailings, soil/sediment and groundwater in and around Khetri. ii. Distribution of some elements in Groundwater and Surface water in Khetri and its surrounding areas. iii. To understand the impact of copper mining on the local environment.

Materials and Methods

Groundwater sampling: A total of 10 groundwater samples were collected in the months of November 2023 respectively. Samples were collected from the underground water sources. To assess the effect of mining on water quality, the sampling sites were selected in the periphery of mining areas, namely, near the mining area, overburden materials, near tailing dam, abandoned mine and also distant places from the mines. The water samples were collected in sample bottles as per set protocols. The first twenty-twenty five strokes of water were discarded before filling the sample bottles in order to minimize the impact of iron pipes. From each location sample was collected in three sample bottles i.e. one sample in 1 liter bottle and two samples in 125 ml of bottles. Total 10 Groundwater samples collected and give the code to each sample GW01 to GW10 Details of sample given in Table-1.

Methods for the pH (Hanna instrument, H196107), EC and Temperature (Aquaphor water tester, model AP-2) were measured in-situ. All the collected water samples were preserved by adding few drops of concentrated Supra-pure HNO_3 followed by filtration and vice versa. The samples were filtered using 0.45 µm Millipore filter paper and stored below 1 liter non-acidified and unfiltered samples were used for analysis of anions namely bicarbonate (HCO_3^-), chloride (Cl^-), sulphate (SO_4^{-2}), dissolved Silica (H_4SiO_4) and nitrate (NO_3-) following the APHA (2012) protocol.

125 ml filtrated and acidified samples were used for analysis of cations such as sodium (Na^+), magnesium (Mg^{2+}), potassium (K^+) and calcium (Ca^{2+}) along with the heavy metal (Cu, Zn, Cd, Pb, Mo, Ni, Fe, Cr and Mn) using Atomic Absorption Spectrophotometer (AAS, Thermo Scientific M series) using air-acetylene gas as a fuel. For the calibration of instrument, standard solutions for each heavy metal were prepared by diluting the 1000 ppm certified standard solution issued by Merck. After every 10 samples, standard solution was measured to test the accuracy and stability of the instrument. The calculated relative error was below 5% indicating the high efficiency of the heavy metal analysis. During the analysis the samples were handled carefully to avoid the contamination.

Results and Discussion

In majority of samples, ion concentrations are above the permissible limits prescribed by the WHO (2011) suggesting the unsuitability of groundwater for human consumption as shown in Table-2.

During the analysis it was found that the samples exceeds the prescribed permissible limit in 10out of 10 samples, Total dissolved solids (TDS) exceed the WHO permissible limit 7 out of 10, the Fluoride contain exceeds in 4 out10 sample, Sulphate exceeds the permissible limit in 4 out 10 samples, Iron exceed the WHO permissibility limit in 4 sample out 10 samples. Excessive Na^+ in drinking water can increase blood pressure in neonates[6]. Presence of excess of Cl in water gives salty taste and increases the risk of bladder and rectal cancer. NO_3- concentration is also in the higher range and exceeds the permissible limits in 2 number of samples during both post and pre monsoon season[7]. Excessive consumption of NO_3- might lead to gastric cancer, methemoglobinemia in infants, goitre, birth malformations and hypertension. The SO_4^{2-} is found within the permissible limit except in the sample collected near tailings[8]. This may be due to leaching of sulphides during rainy season. On comparing with the BIS permissible limit, 6 samples for each Ca^{2+} and Mg^{2+} exceeds the permissible limit. Both Ca^{2+} and Mg^{2+} are important in biological system particularly for the development of bones and nervous system but excess consumption of Ca^{2+} for long duration can lead to formation of kidney stones. Fluoride concentration is also higher in 4 samples, it is the cause of the fluorosis disease[9]. Comparative analysis has been shown in Fig1 to16 elaborately.

Table-1: Groundwater samples collected and give the code to each sample GW01 to GW10.

Sample code	Sample Location	UTM
GW01	Copper town	E-580781.00 m N-3105710.00 m
GW02	Near Banwas	E-581439.00 m N-3106938.00 m
GW03	Singhana	E-581287.00 m N-581287.00 m
GW04	Banwas	E-579734.00 m N-3106806.00 m
GW05	Near Gothra Village	E-580191.00 m N-3104743.00 m
GW06	Dhani Bhargran	E-579386.00 m N-3103144.00 m
GW07	Nanoowali Baori	E-578791.00 m N-3101323.00 m
GW08	Kharkhara	E-576200.00 m N-3102397.00 m
GW09	Near Kharkhara	E-577580.00 m N-3104351.00 m
GW10	Makro	E-578173.00 m N-3107009.00 m

Table-2: Permissible limits of groundwater parameters as provided by WHO standards.

Parameters	Unit	WHO (2011) Desirable	Desirable Limits	Permissible Limits
pH	-	6.5-8.5	6.5 to 8.5	N.R.
Electrical Conductivity	µS/cm	750	--	--
Turbidity (NTU)	NTU	-	<01	<05
Total Dissolved Solids	mg/l	600	<500	<2000
Total Suspended Solids	mg/l	-	--	--
Total Hardness	mg/l	-	<200	<600

Calcium Hardness	mg/l	75	<75	<200
Magnesium Hardness	mg/l	50	<30	<100
Total Alkalinity	mg/l	-	<200	<600
Nitrate (as NO_3)	mg/l	10	<45	N.R.
Chloride (as Cl)	mg/l	250	<250	<1000
Sulphate (as SO_4)	mg/l	250	<200	<400
Iron (as Fe)	mg/l	-	<0.3	N.R.
Sodium (as Na)	mg/l	200	--	--
Potassium (as K)	mg/l	12	--	--
Fluoride (as F)	mg/l	-	<1.0	<1.5
Silica	mg/l	-	--	--
Phosphate (as PO_4)	mg/l	-	--	--
Carbonate	mg/l	120	200	600

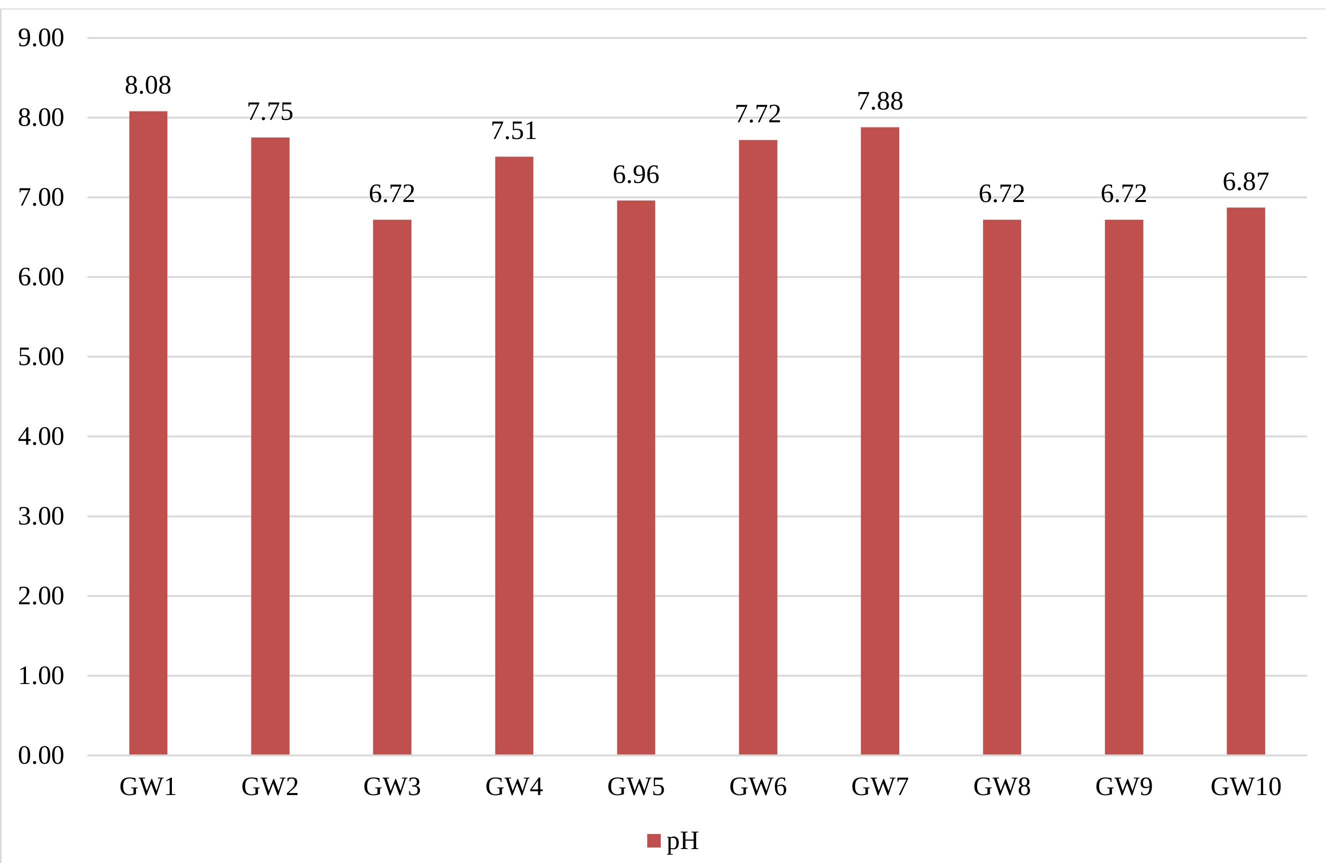

Figure-1: pH of Command (Near Khetri Copper Mine) Area.

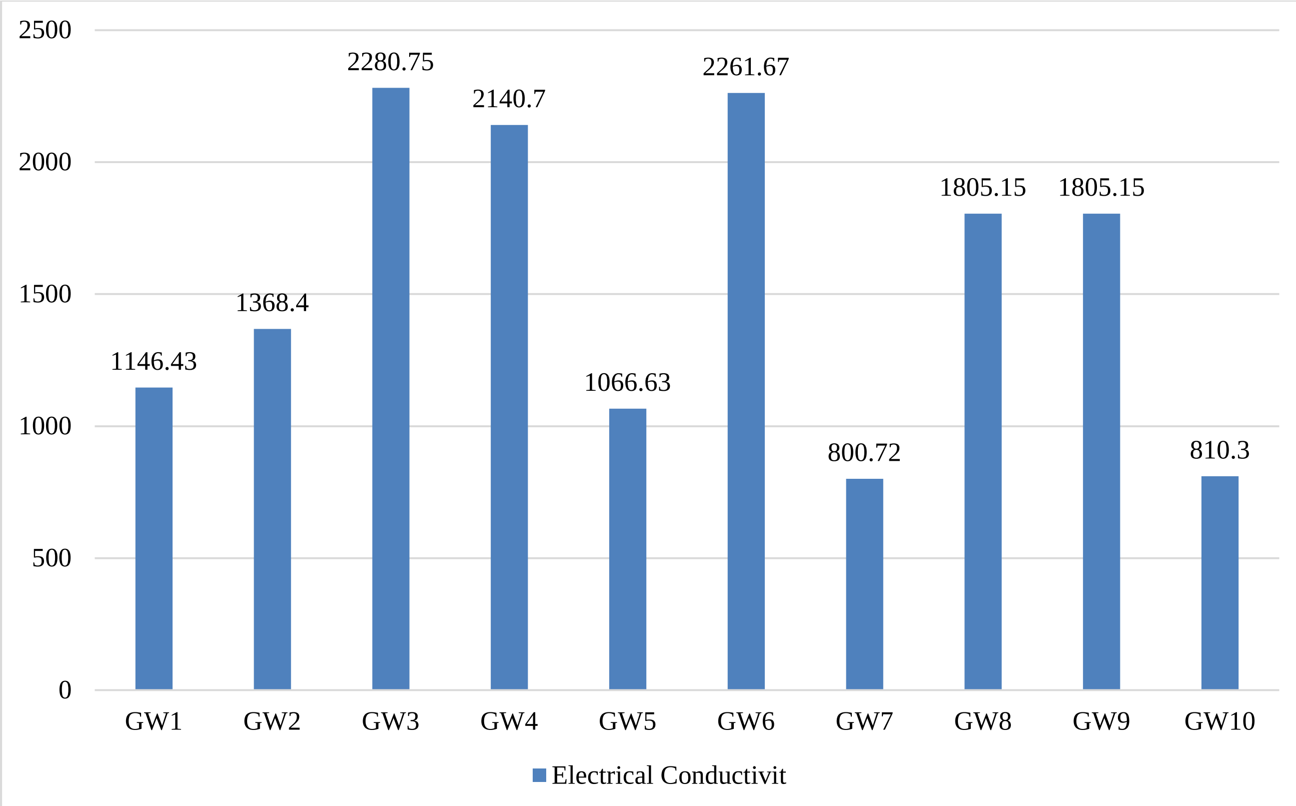

Figure-2: Electrical Conductivity of Command (Near Khetri Copper Mine) Area.

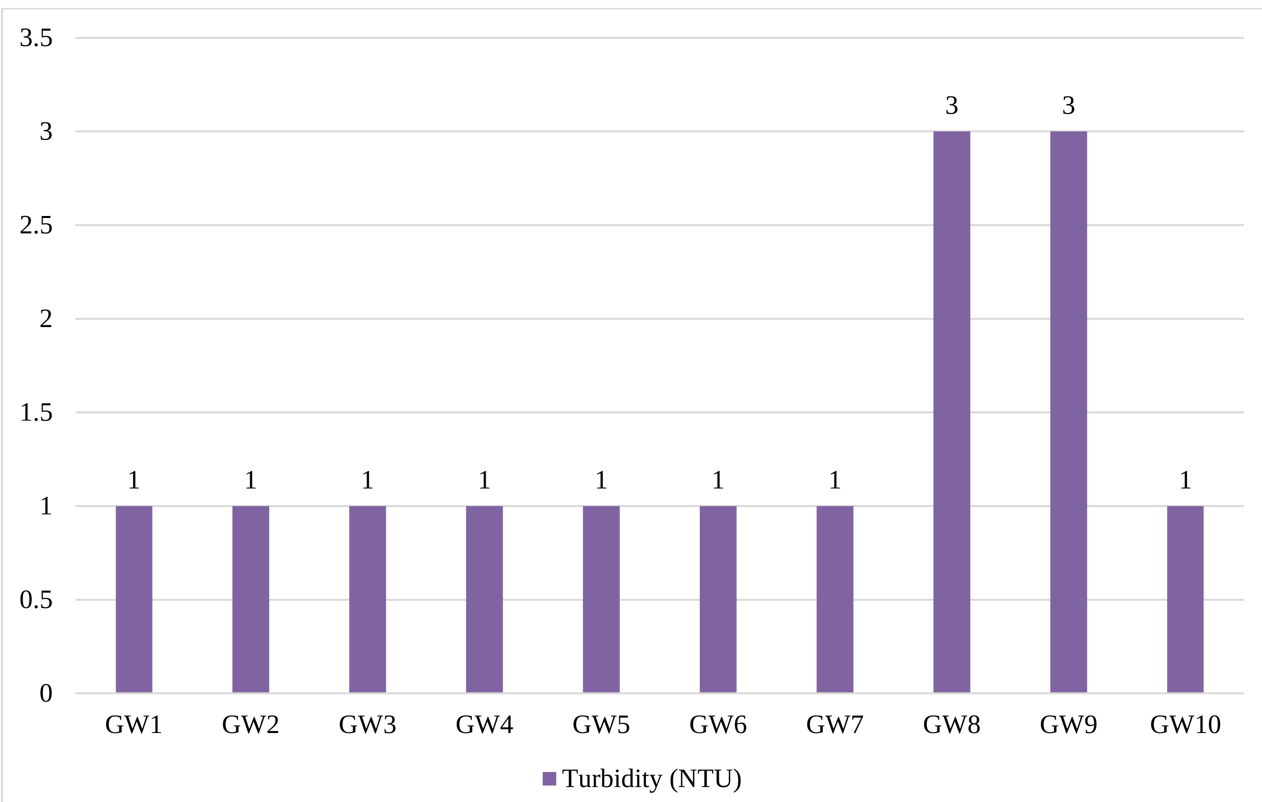

Figure-3: Turbidity of Command (Near Khetri Copper Mine) Area.

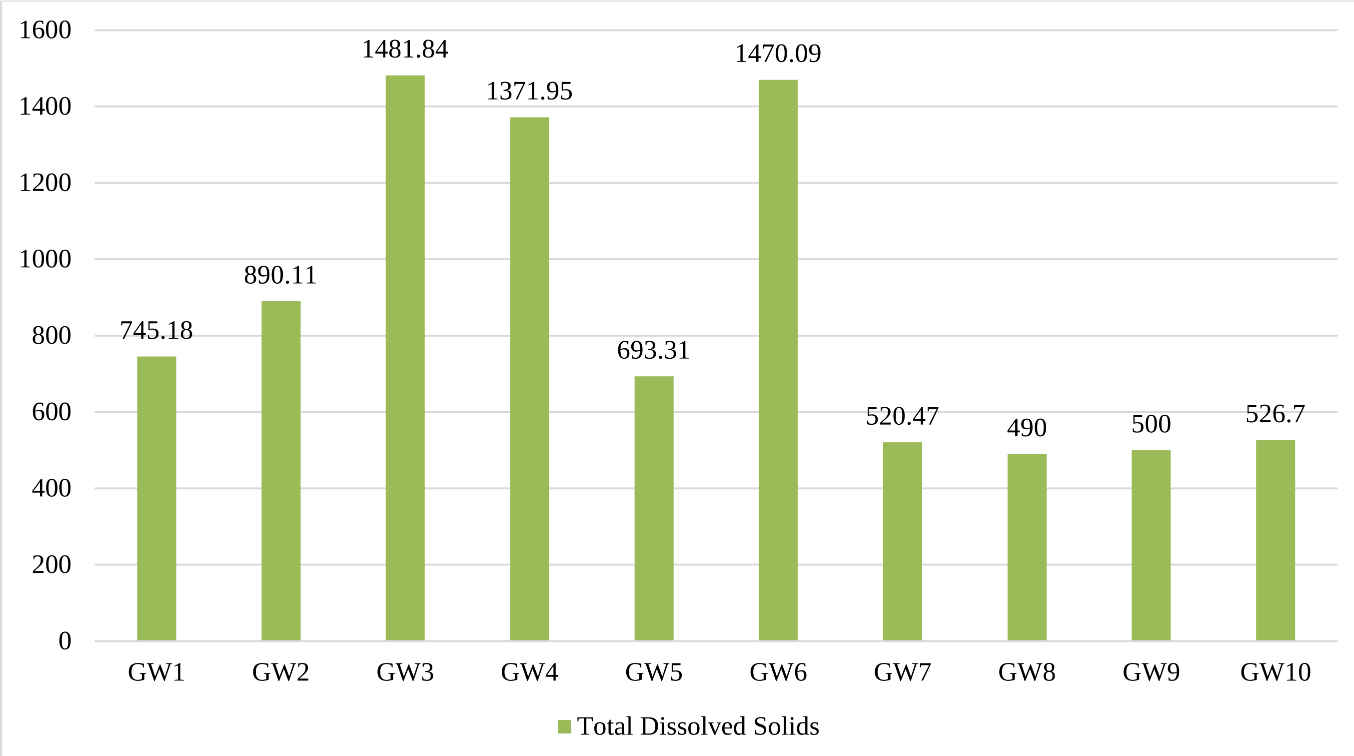

Figure-4: Total Dissolved Solids of Command (Near Khetri Copper Mine) Area.

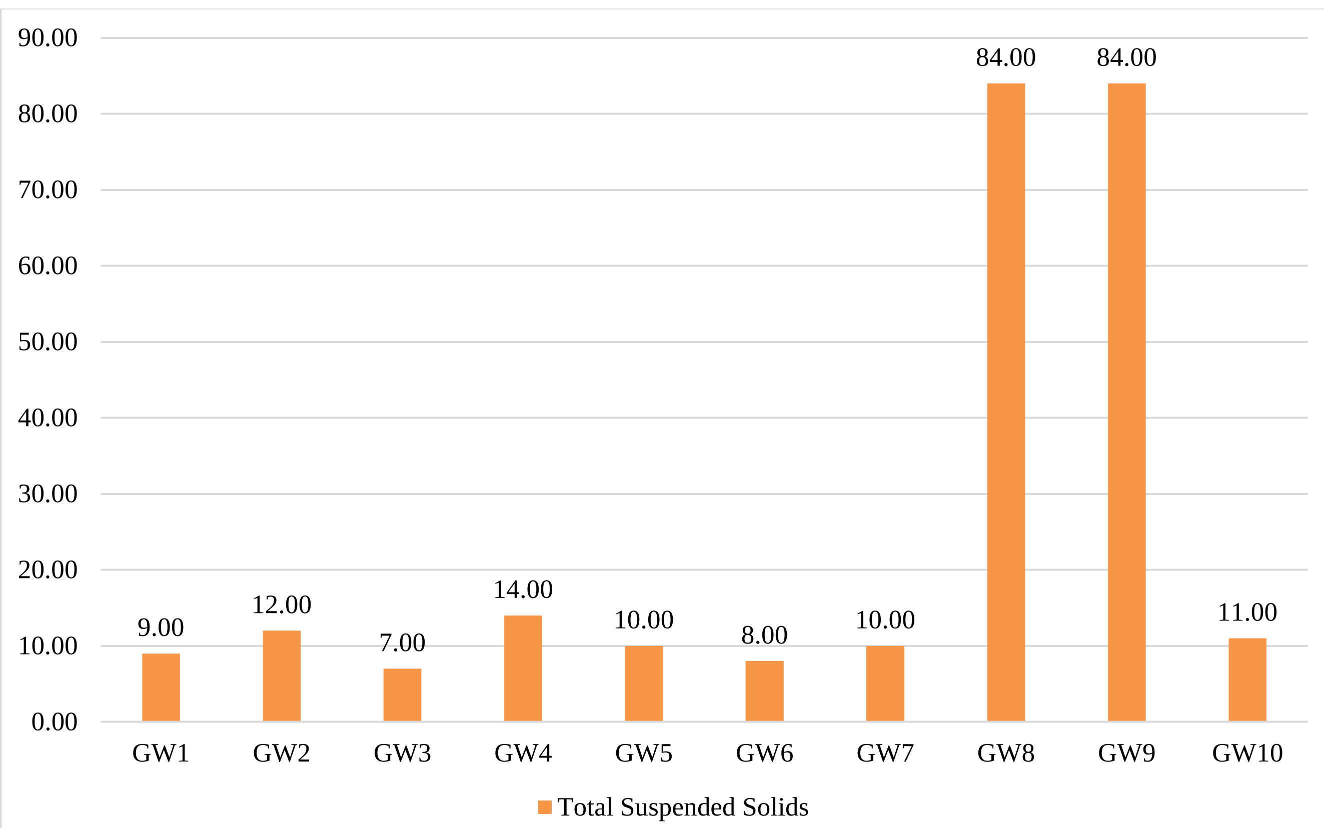

Figure-5: Suspended Solids of Command (Near Khetri Copper Mine) Area.

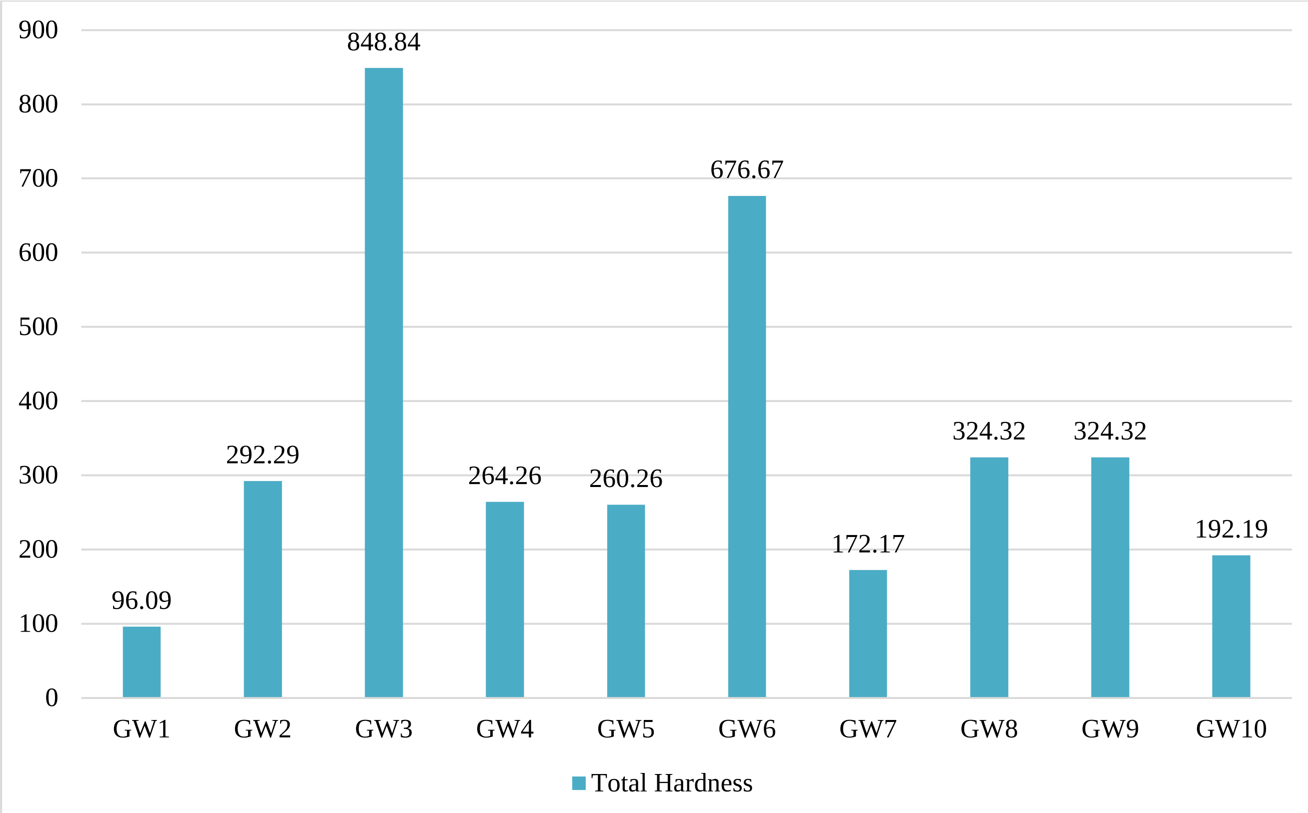

Figure-6: Total Hardness of Command (Near Khetri Copper Mine) Area.

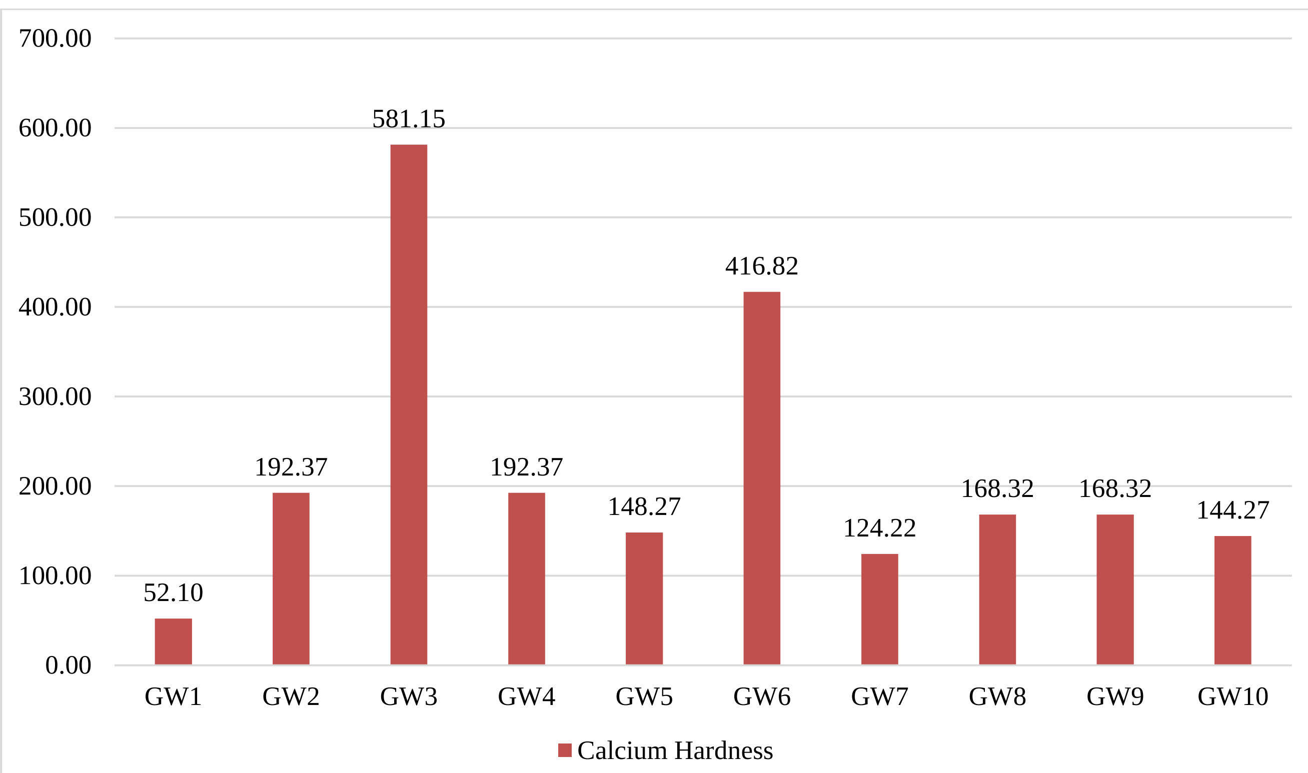

Figure-7: Calcium Hardness of Command (Near Khetri Copper Mine) Area.

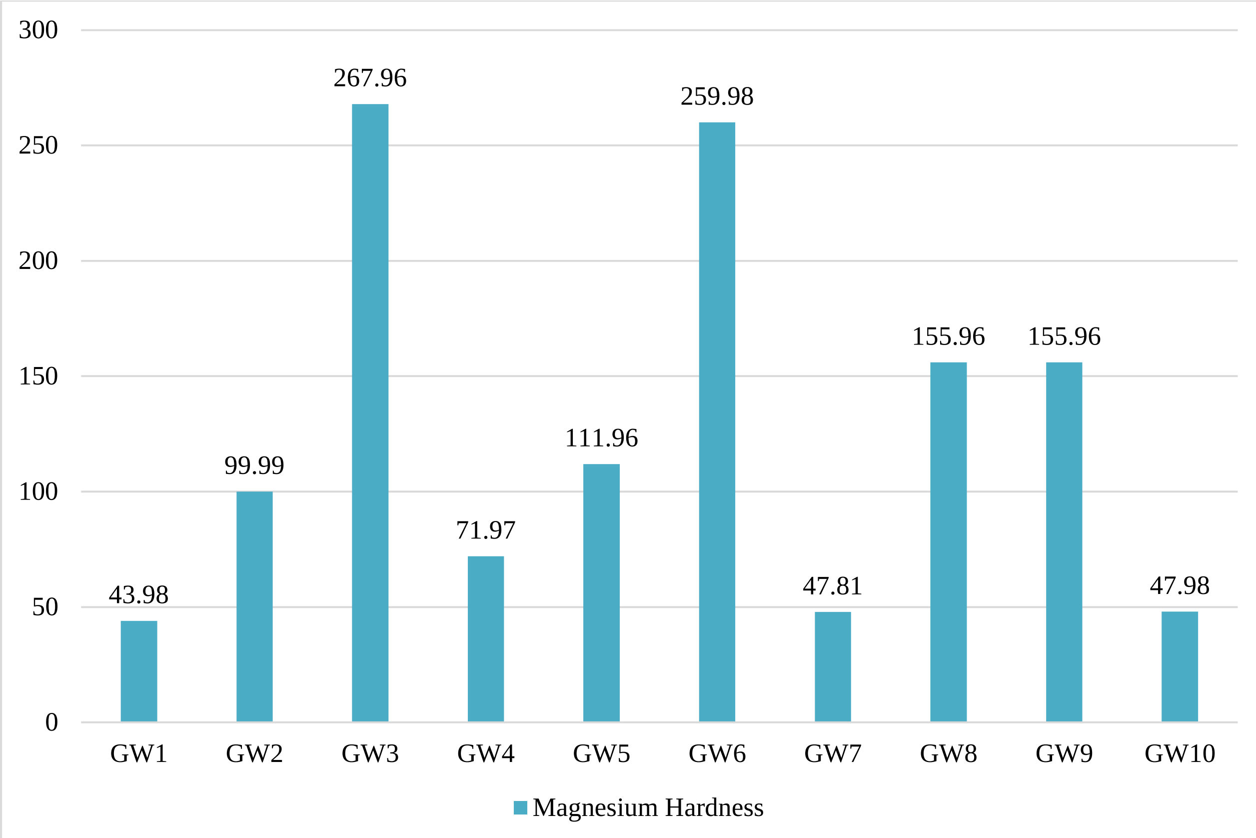

Figure-8: Magnesium Hardness of Command (Near Khetri Copper Mine) Area.

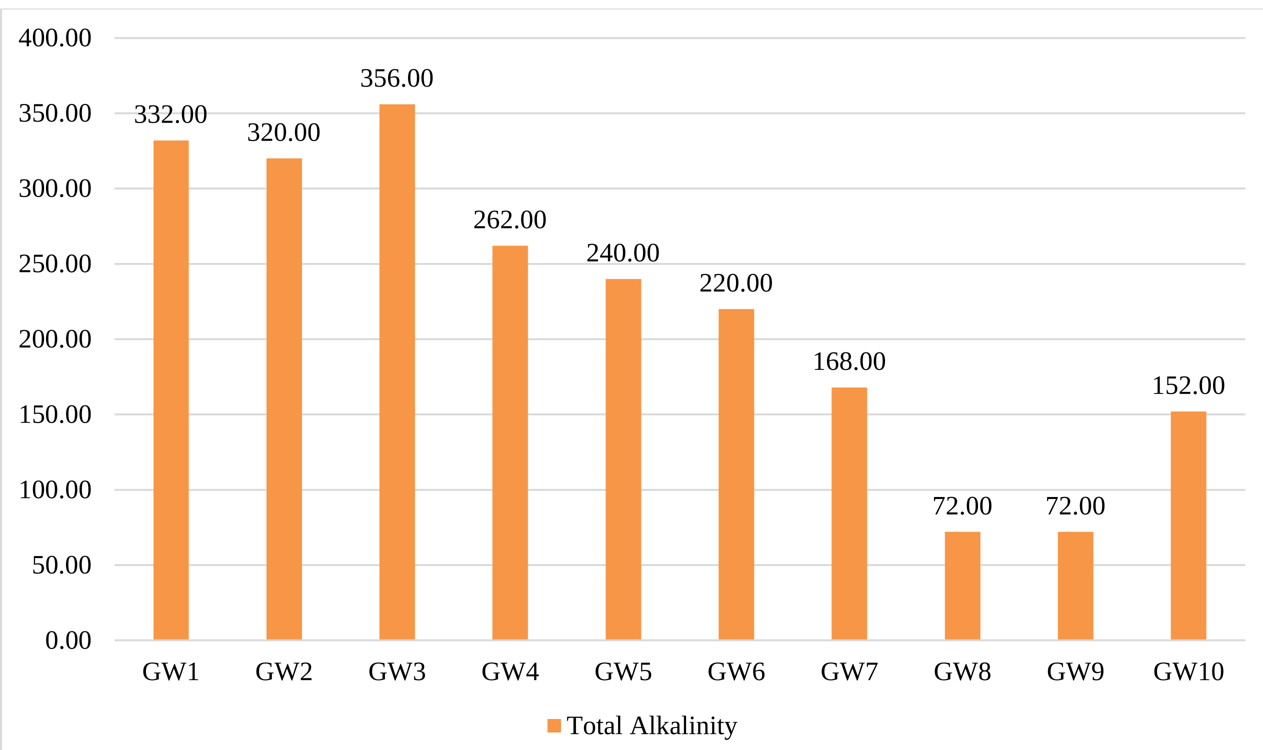

Figure-9: Total Alkalinity of Command (Near Khetri Copper Mine) Area.

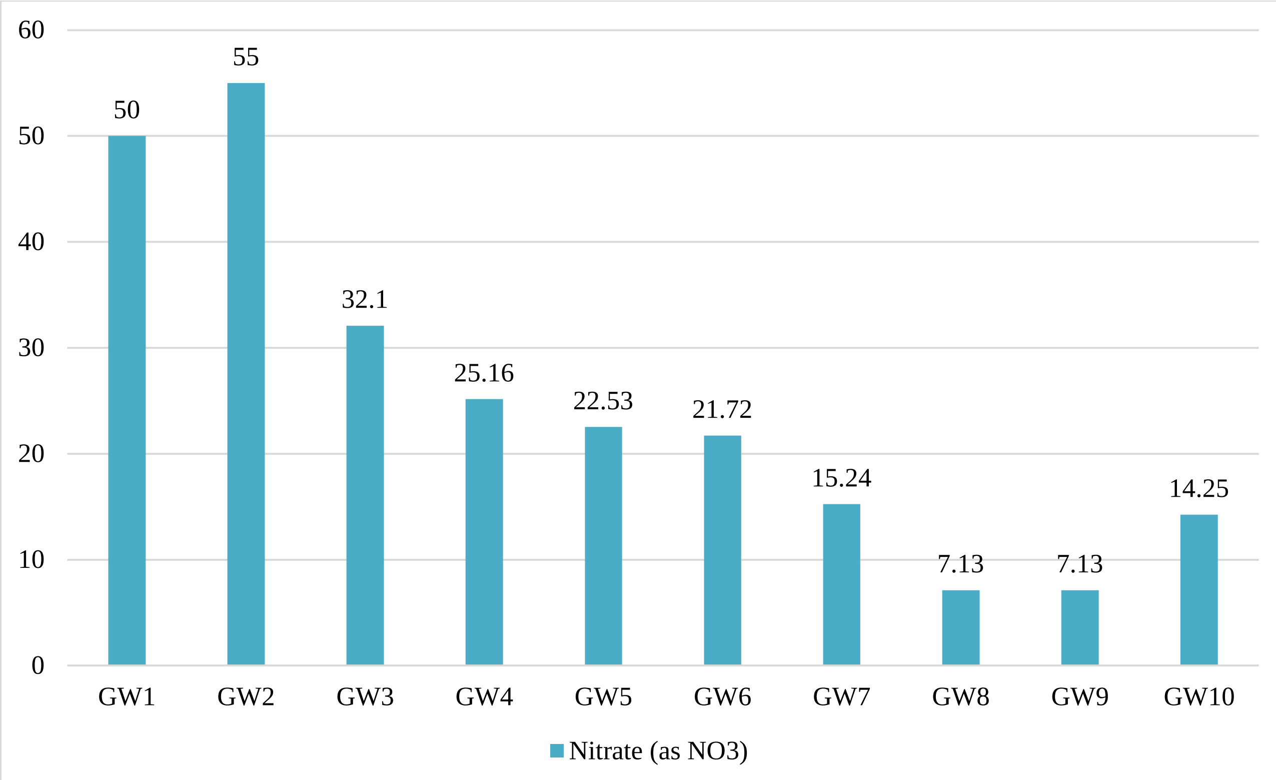

Figure-10: Nitrate of Command (Near Khetri Copper Mine) Area.

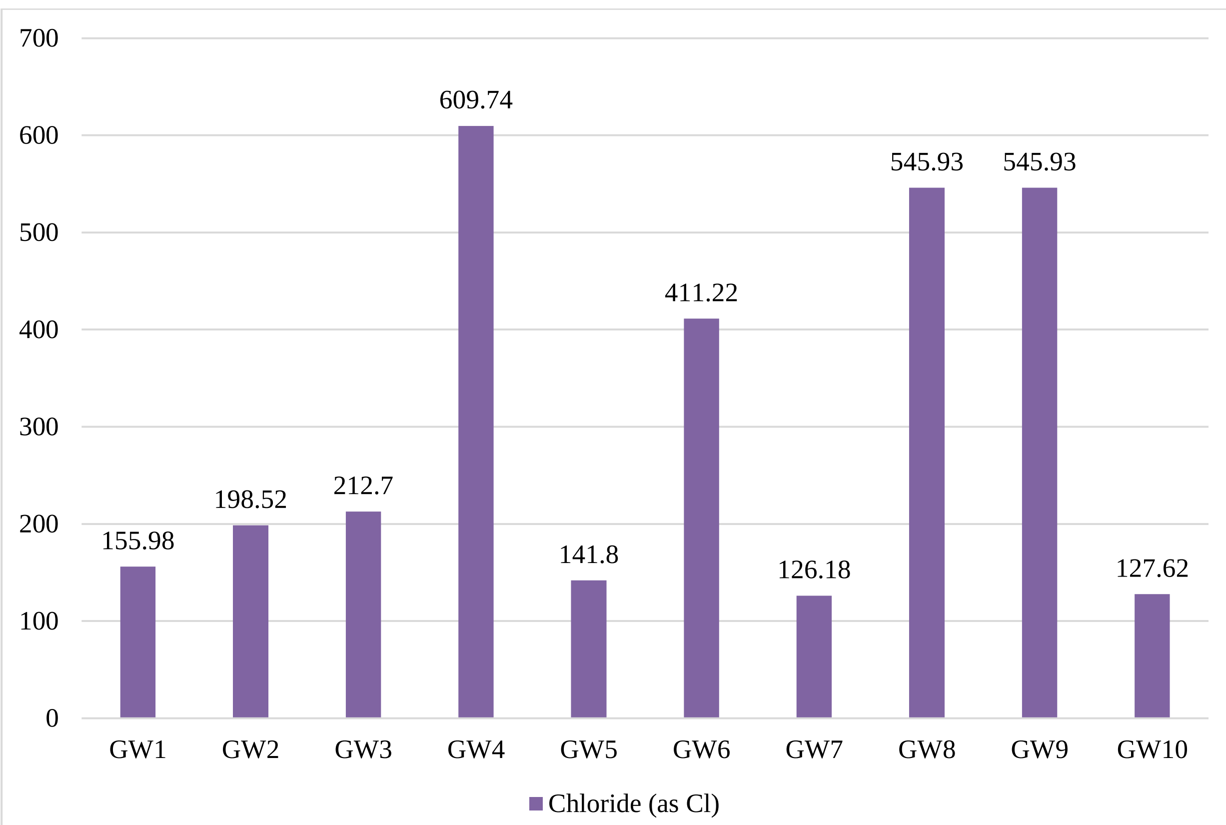

Figure-11: Chloride of Command (Near Khetri Copper Mine) Area.

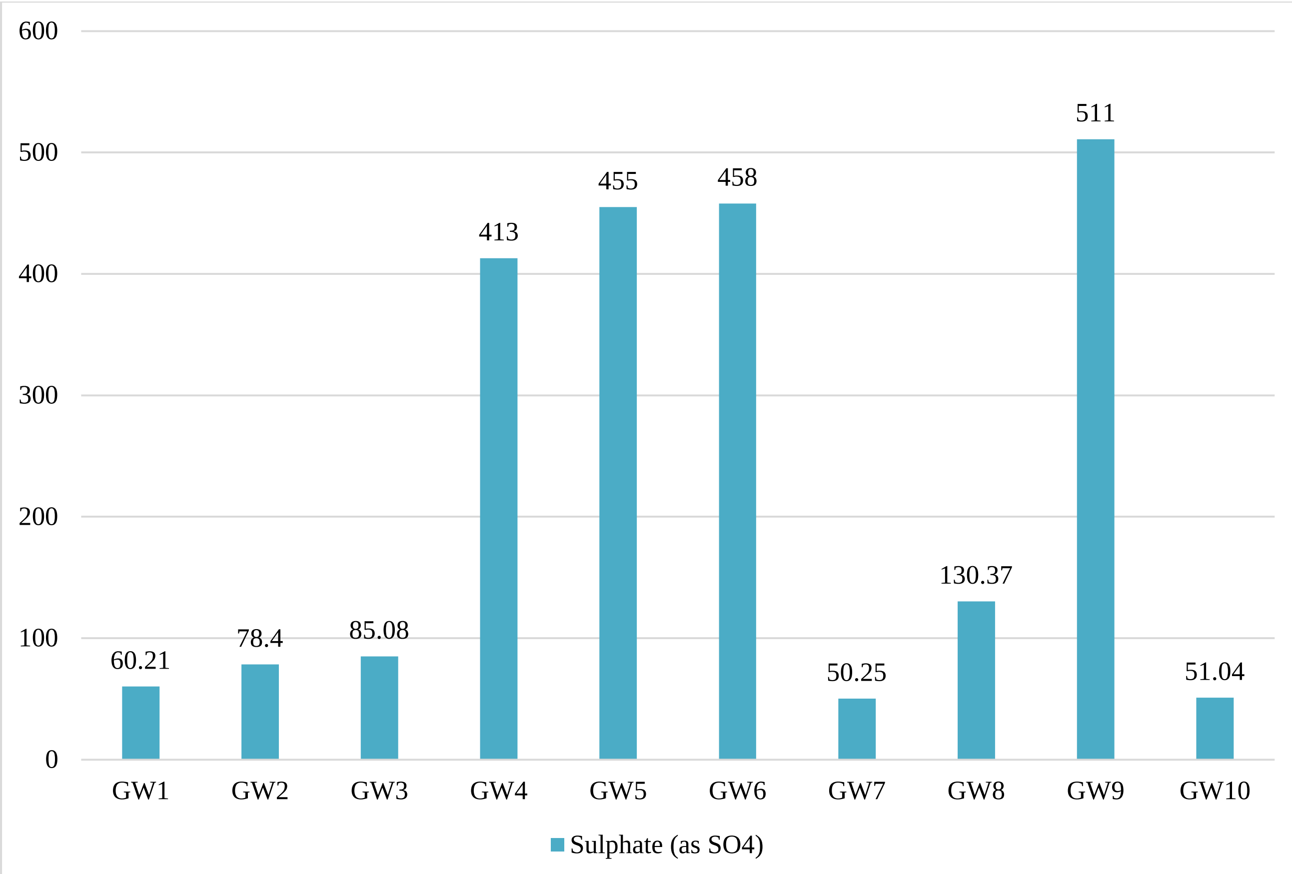

Figure-12: Sulphate of Command (Near Khetri Copper Mine) Area.

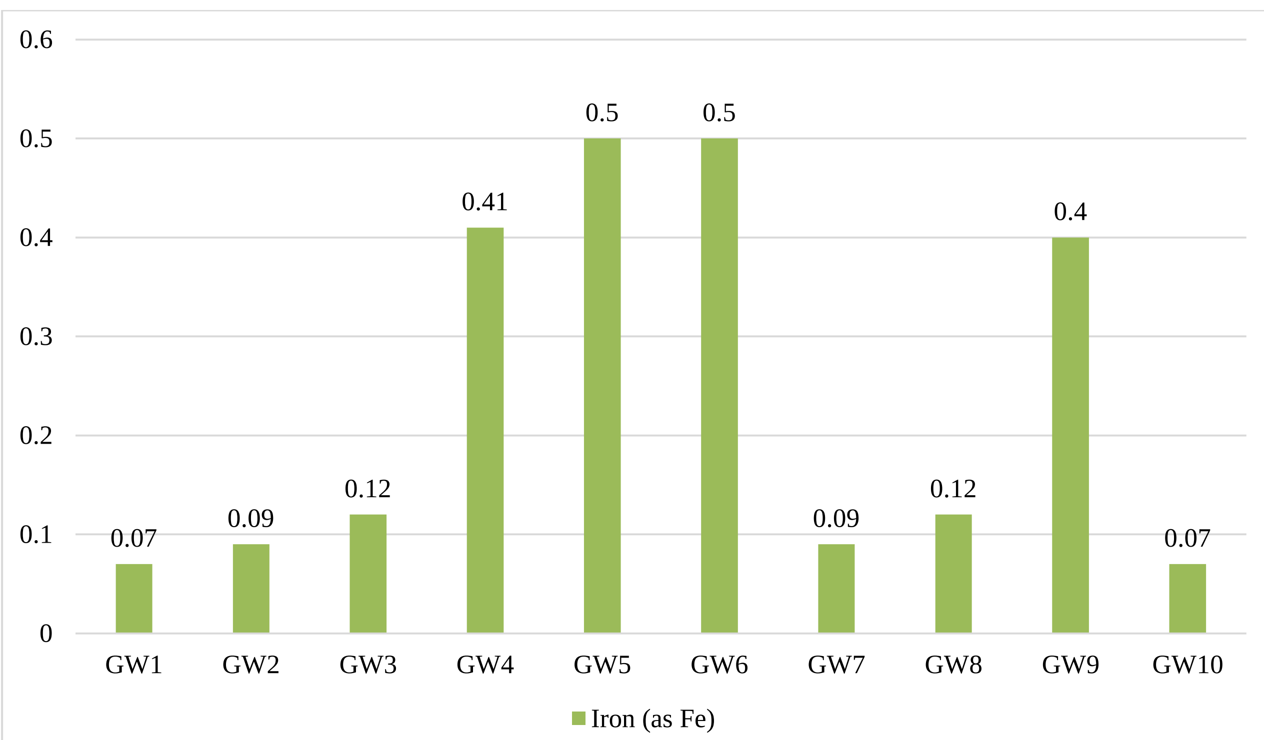

Figure-13: Iron of Command (Near Khetri Copper Mine) Area.

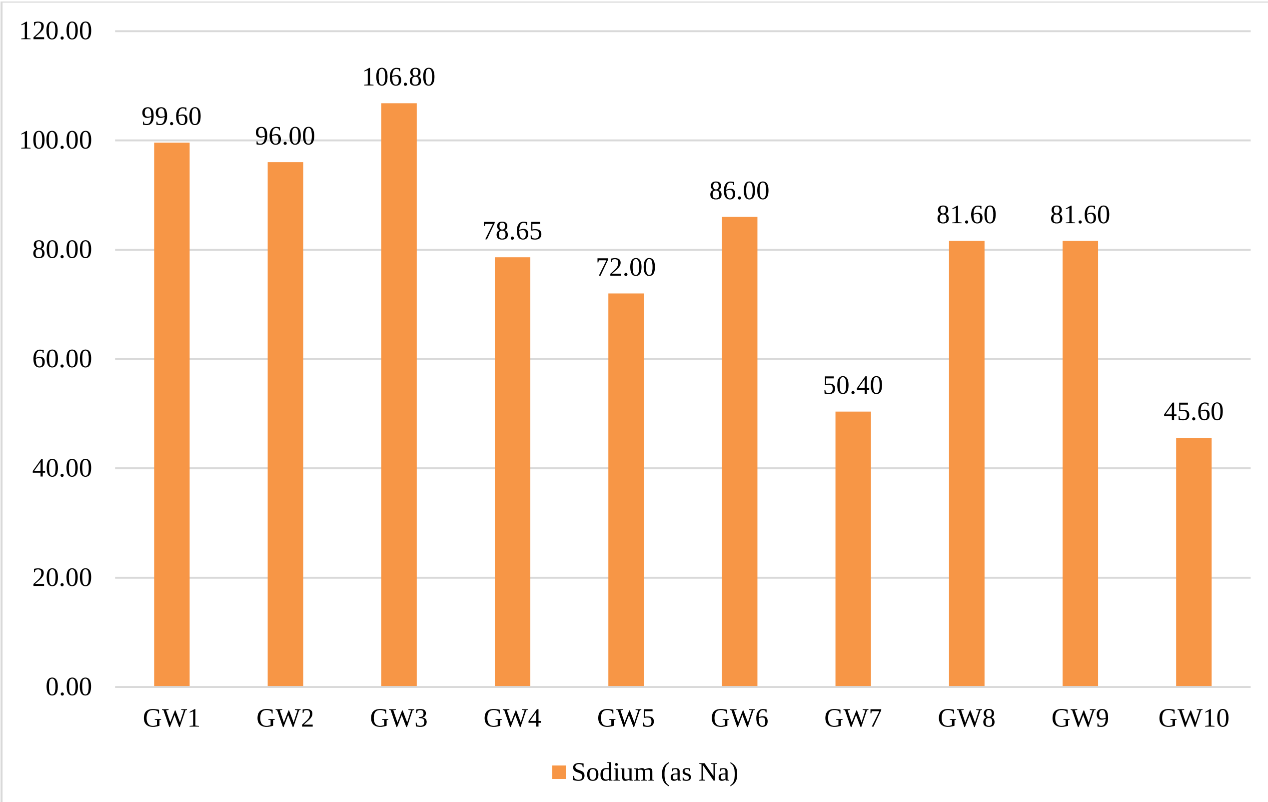

Figure-14: Sodium of Command (Near Khetri Copper Mine) Area.

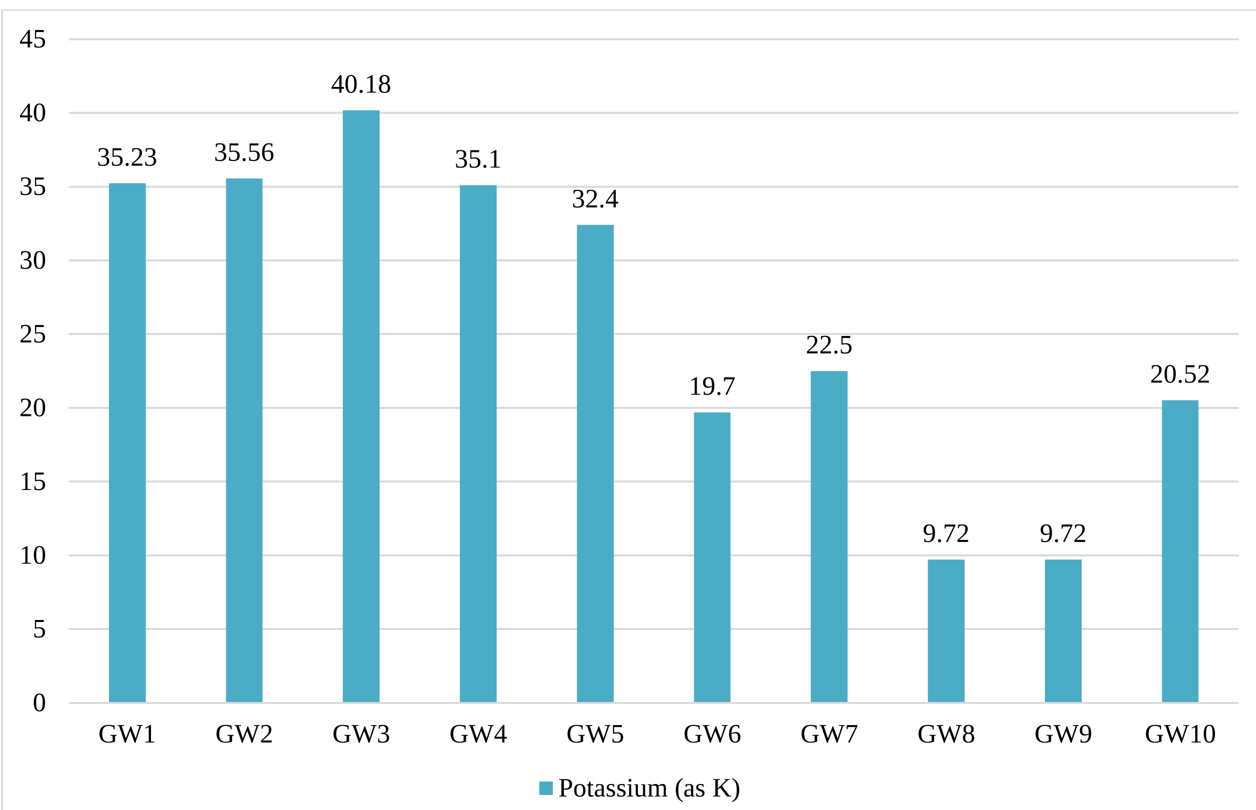

Figure-15: Potassium of Command (Near Khetri Copper Mine) Area.

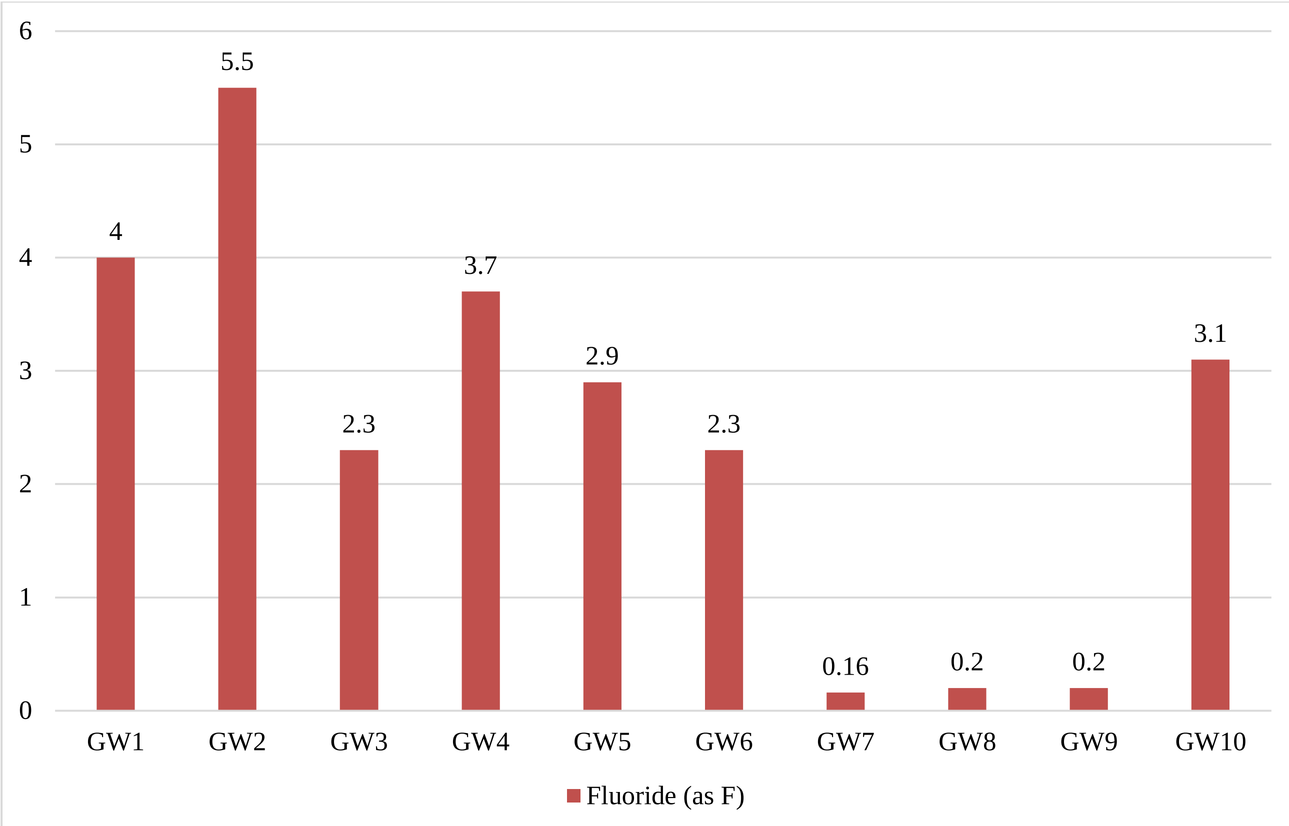

Figure-16: Fluoride of Command (Near Khetri Copper Mine) Area.

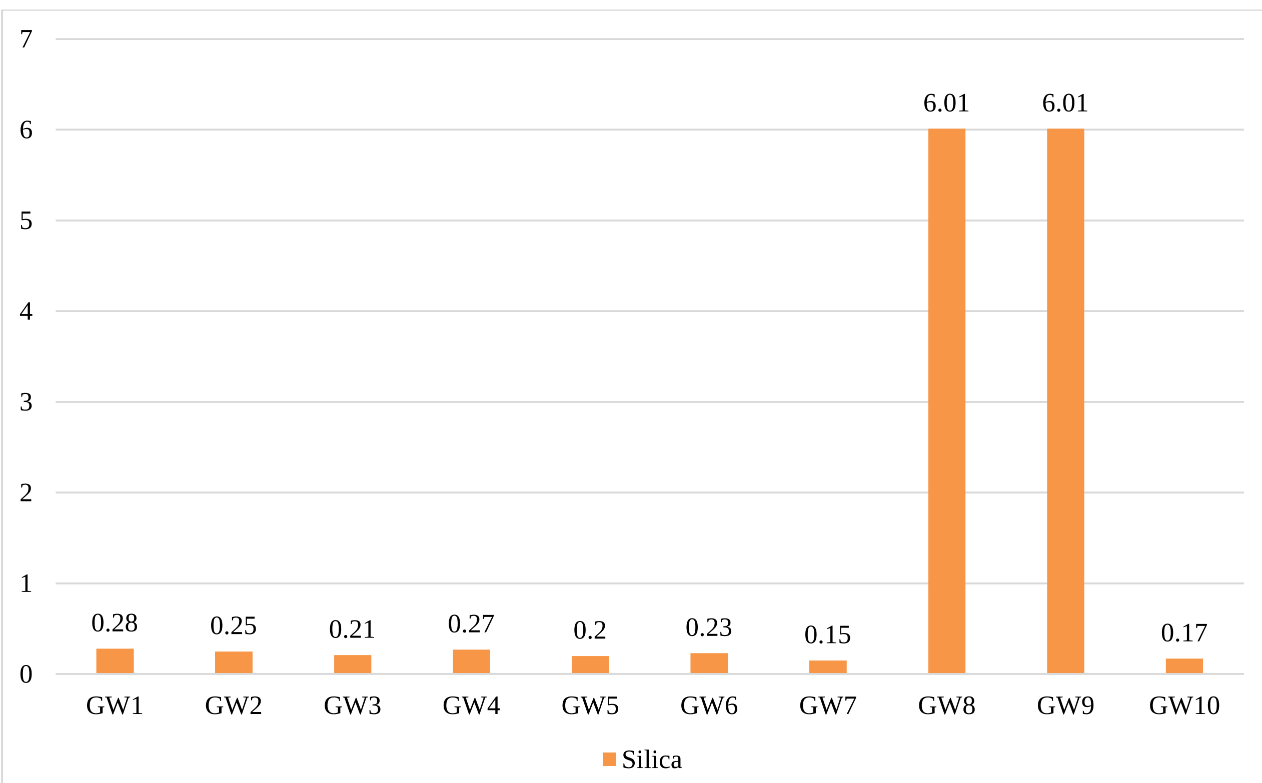

Figure-17: Silica of Command (Near Khetri Copper Mine) Area.

Conclusion

Systematic field and laboratory studies on the distribution and behaviour of heavy metals turbidity alkalinity in general and Cu in particular in ground water, surface water and from the Khetri copper mining region of Rajasthan were carried out to understand the impact of copper mining on the immediate environment. Based on field and extensive laboratory data along with the calculated pollution indices of heavy metals, following are some of the salient findings on physiochemical characteristics of tailings; nature, mineralogy and geochemical makeup of soils; behaviour of heavy metals in tailings and soils; quality and chemical composition of waters; heavy metal abundances in several types of vegetables; probable source(s) of various elements in both water and soils in addition to the status of heavy metal pollution in the environment of the region[10]. Accordingly, potential management strategies of mine tailings and overburden materials are proposed to prevent and/or reduce heavy metal pollution for a sustainable ecosystem. The groundwater of Khetri is neutral to slightly alkaline (pH =7 to 8). It is hard (TH = 96-848 mg/L) with an average EC of ~800-2000 µs/cm respectively. The groundwater consists dominantly of Ca^{2+} (units are in mg/L: 52-581), Mg^{2+} (44-268), Na^{+} (45-105.80), and Cl^{-}155.98-609.74) and all exceed the WHO (2011) and BIS (2012) permissible limits. The abundances of major ions are more in groundwater samples around the mining activities (GW4, GW6 and GW9). Based on calculated TH (96 mg/L -848 mg/L) and WQI (173-179), the groundwater in Khetri region is unsuitable for drinking purposes. Higher EC (~800 and 200µs/cm), magnesium hazards (MH) and permeability index (PI) suggest its unsuitability for irrigation. Equal dominance of alkaline earth elements (Ca^{2+} + Mg^{2+}) and alkalis (Na^{+} + K^{+}), along with dominance of strong acids (Cl^{-}) over weak acids (HCO_3^{-}) suggest influence of silicate weathering and anthropogenic activities in the region. The observed significant positive correlation between major cations (Ca_2^{+}, Mg_2^{+} and Na^{+}) and SO_4^{2-} suggests weathering of sulphides in the region. Absence of correlation between major cations (Ca^{2+}, + Mg^{2+} and Na^{+}) and HCO_3^{-} indicates either lack of carbonate weathering or dominance of silicate weathering in the region. The observed high EC and major ion concentration in the groundwater samples surrounding the mines, overburden materials and tailings are due to dissolution of minerals by AMD. Hence, assessment and monitoring of waste is important to avoid the environmental contamination in the mining region.The heavy metal concentration data on majority of groundwater samples in the Khetri region indicate that they exceed the desirable limits set by WHO, 2011 and BIS, 2012.

Recommendation: The soils, groundwater and vegetables in Khetri and surrounding areas within the limits of this study suggest a significant concentration of heavy metals largely from mining and related activities in the area. Enrichment factors, pollution load and geo-accumulation indices on the samples studied indicate enrichment of heavy metals above their respective background concentrations as well as permissible limits[11]. The degree of contamination of heavy metals has been observed to decrease farther downstream and away from the contamination sources i.e. tailings and overburden materials[12]. The research highlights the impacts of mining, mine waste, and the improper disposal of mine waste on the quality of soils and water, and effects on food quality. Therefore, in order to ensure no or minimal effects on soils and water resources, the following action plan is suggested. Studies to explore on the management options for existing tailings and overburden materials to minimise their impacts on human health and environment are warranted. Application of effective and efficient methods of metal milling and beneficiation technologies in order to minimize the concentration of copper in tailings and thus in environment (soils, water, air and crops)[3]. It is essential to recover the Cu from the existing tailings so as to minimize their further impact on the environment. Reclamation of the open pit mine areas to the conditions capable of supporting alternative sustainable land uses. The observed higher concentration of Cu in the vegetables of Khetri area is a cause of serious concern, and therefore, its potential toxic effects on the health of the people in the region needs to be studied.

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