SOME STUDIES ON THE STATUS OF WATER QUALITY IN AN ABANDONED OPENCAST LIMESTONE & DOLOMITE QUARRY

Dr. D.P.Tripathy
(Department of Mining Engineering, NIT, Rourkela)
A. Sisodia
(Department of Mining Engineering, NIT, Rourkela)

Abstract: The present paper summarizes the outcome of preliminary investigations carried out for assessing water quality parameters in an abandoned opencast limestone and dolomite quarry. From the experimental results it was observed that the overall water quality of the water was good and some of the parameters like turbidity (23-32 NTU) and calcium (98-102 mg/L) and magnesium hardness (54-61 mg/L) were slightly greater than the prescribed statutory limits. It can be used for various end uses with minor treatment.

1. INTRODUCTION

The issue of abandoned mines is important because it represents many thousands of former mining sites that continue to pose a real or potential threat to human safety and health and/or environmental damage. In many areas this is considered a negative legacy of the mining industry and is important because it both demonstrates a lack of care and planning in past practice and adherence to regulations that were inadequate because of the lack of detailed understanding. Orphaned or abandoned (O/A) mines are mines for which the owner cannot be found or is financially unable or unwilling to carry out site rehabilitation/ clean-up.

Abandoned sites and orphan sites refer to mine sites and mineral operations that are: no longer operational; are not actively managed; not rehabilitated; are causing significant environmental or social problems; and for which no one is currently accountable for the site's remediation or rehabilitation. The term "abandoned mine" generally applies to a mineral excavation or surface disturbance and associated facilities where mining operations have been permanently terminated. The term "abandoned historical mine" refers to an abandoned mine that was operated and abandoned before the enactment of modern environmental laws. When no owner, operator or other party responsible for the abandoned mine can be identified, it is referred to as an "orphan mine."

The environmental, social and economic problems associated with abandoned mine sites are serious and global. The physical impacts of abandoned mine sites include: altered landscape; unused pits and shafts; land no longer usable due to loss of soil, pH, or slope of land; abandoned tailings dumps; changes in groundwater regime; contaminated soils and aquatic sediments; subsidence; and changes in vegetation. These problems have social and economic impacts on countries and individual communities due to: loss of productive land; loss or degradation of groundwater; pollution of surface water by sediments or salts; fish affected by contaminated sediments; changes in river regimes; air pollution from dust or toxic gases; risk of falls into shafts and pits; and landslides. Water impacts from mining occur on and below the surface. Exposed rocks, metals and ores can undergo naturally-occurring chemical reactions when exposed to water over time, leading to pollution from acidity or heavy metal content. Surface runoff can carry AML-originated silt and debris down-stream, eventually leading to stream clogging. Sedimentation results in the blockage of the stream and can cause flooding of roads and/or residences and pose a danger to the public. Sedimentation may also cause adverse impacts on fish. This paper is an attempt to carry preliminary assessment of water quality in an abandoned limestone mine near Rourkela.

2. IMPACT OF METAL MINING ON WATER

Mining and associated activities have quantitative and qualitative impacts on the water regime in and around the mines. These are briefly outlined hereunder:

- All the surface water bodies have to be removed from the area designed for the mining and associated activities.
- All the aquifers, including the water–table aquifer, above the mineral deposit to be extracted are likely to be affected.
- Water in the nearby water bodies gets polluted due to leaching from the overburden dumps, discharge of pumped mine water, and other activities in the vicinity of the water bodies.
- During rainy season the runoff water from the areas surrounding the mines carries with large quantity of the suspended solids into the nearby water bodies.

It is evident from the above that the mining and associated activities changes in ground water flow patterns, lowering of water table, changes in hydrodynamic conditions of river/underground recharge basins, reduction in volumes of subsurface discharge to water bodies/rivers, disruption and diversion of water courses/drainages pattern, contamination of water bodies, affecting the yield of water from bore wells and dug wells etc. Therefore, it is necessary to plan the mining and associated activities in such a manner that their impacts on the water regime are as minimum as possible.

3. SOME PREVIOUS STUDIES ON WATER QUALITY MONITORING IN MINING AREAS

Singh (1997) did a number of experiments on Environmental Impact Assessment of mining projects and concluded that the major impacts of mining are water pollution due to the erosion, oil and grease, contamination of water bodies due to the discharge of mine water effluents, leachates from wash-off dumps, solid waste disposal sites, toxic wastes, salinity from mine fires, acid mine drainage etc. He listed major mitigation methods as follows: Overburden run-off collection and treatment with subsequent sediment control, Oil and grease separators, Collection/storage of leachates, seepages, wash-offs with subsequent treatment, Proper sanitation and provision of the domestic and the sewage effluents treatment, Treatment of mine water discharges. He suggested that there is an acute shortage of water supply in mining areas, augmentation of underground pumped out mine water for various supplies can be provided. This is a very economically cost-effective and provides savings towards water and energy conservation while giving the environmental and the social benefits.

Roy et al. (2003) after carrying out a number of experiments found out that mining affects huge area of the land and affect the quality of surface and underground water by adding contaminants and toxic compounds making it unsafe for drinking and industrial usage, disturbing the hydrology of the area. They discovered that the major sources of liquid effluents were: surface run-off, mine water pumped put during drainage operation, spent water from handling plants, dust extractors and dust suppression systems, effluents from preparation and beneficiation plants, and leaches/wash-off from waste/tailing dumps. Plant spillage, truck haulage, conveyor transfer points, and rail wagon loading areas, are common sources contributing fines top the surface run-offs. Abandoned mill tailings, coal refuse heaps, spoil heaps, and other waste dumps in mining area contain significant amounts of dissolved minerals, are chronic sources of stream pollution, apart from presenting eye-sore sights. Mining is also responsible for changing the hydrology of an area in many ways. Subsidence due to underground mining affects underground water, disruption of surface drainage patterns and resulting contribution to stream pollution. Sometimes it may change the river course and discharge, there by affecting the agriculture and flora and fauna of the area.

Lambert (2004) worked on the long-term changes in quality of discharge water from abandoned underground coal mines and he observed that in several areas of Appalachian coalfields and in coal mining regions of the UK, mine water acidity and iron load are most severe in the first years after a discharge begins, but decreases steadily and substantially with the time. Their study was to document the extent of the water-quality changes in the Uniontown Syncline acid mine drainage discharges, and to investigate the geochemical and hydraulic factors responsible for changes. While in the operation, the advantage of these mines was the fact that water did not pool and hinder mining activities, but rather travelled down slope and out of the mine. The discharge from Uniontown Syncline Pittsburgh coal seam flow in to two major streams, or their tributaries: the Youghiogheny river in the north part of the Syncline, and Redstone Creek in the south part. But the method followed for this study included: Sample collection from the 22 sites and field measurements of pH, temperature, dissolved oxygen, conductivity, ferrous iron and flow. Results were recorded and compared with results from Scar lift study. Thus Long-term changes in quality of abandoned underground coal mine discharges were studied. The study presented the clear evidence for natural improvement of the quality of drainage for abandoned mine discharges. They suggested that the type and magnitude of the water-quality changes that occurred over time, mainly depends on degree of flooding within the mine voids contributing to discharges and the time elapsed since mine abandonment.

Heyden (2005) carried out a number of experiments and observed that the use of wetlands to treat mine effluent has grown in popularity over the past two decades, although the processes by which the natural systems function are often poorly understood. This field-scale investigation utilizes daily data over a 9-month period in assessing the processes leading to the remediation of mine effluent within a natural wetland on the Zambian Copper belt. The study differentiates effluent remediation through dilution from pollutant retention. Decreased wetland outflow concentrations of SO_4 and Na are due to dilution only, while Co (50%) and especially Cu (83%) are retained within the wetland. Retention was linked to adsorption onto new or primed surfaces during an initial period of effluent release into the system and to processes related to pH buffering to 7.5. The wetland's acid buffering capacity was largely the result of carbonate-rich groundwater discharge into the wetland. Although this buffering capacity likely shows little seasonal fluctuation (20–80 kmol/day), the impact of acidic effluent input on the wetland itself probably varies markedly between seasons, owing to the temporal and spatial characteristics of discharge from the catchments aquifers. Assessment of other natural wetlands in the region indicated that some (circa 15%) showed similar catchment size, hydro chemical and hydrogeological characteristics as those of the New Dam wetland, likely demonstrating a similar effluent remediation potential as that described here.

Roychoudhury (2006) comprehended and assessed the potential threat of metal pollution from dewatering of Grootvlei Gold Mine effluent into the Blesbokspruit, a Ramsar certified wetland site, the Witwatersrand rock of this area contains sulphide minerals, like pyrite pyrrhotite, arsenopyrite, chalcopyrite, galena cobaltite, gersdorffite, Fe, Ni, Pb, Cu, Co, As and U-bearing leachable oxides (Scott). Groundwater seeps through the mineral reef, therefore, has high Fe, SO_4 and trace metal content. Effluent pumping subsequently resulted in disposal and dispersal of trace metals in the surface water system. Blesbokspruit stream recharges the local dolomite aquifer. The poor water quality therefore is likely to impact the freshwater resources in the area like Vaal river. The assessment was carried out by surface water and sediment sampling, determination of water chemistry by pH, electrical conductivity (EC), dissolved O_2 (DO), redox potential (Eh), temperature, ion Chromatograph (Dionex, DX500) and atomic absorption spectro-photometry test, which was followed by Leachate test using ICP-MS., CHN analyzer to determine the organic C in the sediment. They also assessed the sediment quality by determining Enrichment factor (Ef), Geoaccumulation index (Igeo), Metal Pollution Index (MPI) and Sediment Quality Guideline Index (SQG-I).

Kumar (2008) checked the chemical characteristics of surface, groundwater and mine water of the upper catchment of the Damodar River basin and conducted studies to evaluate the major ion chemistry, geochemical processes controlling water composition and suitability of water for domestic, industrial and irrigation uses. Water samples from ponds, lakes, rivers, reservoirs and groundwater were collected and analysed for pH, EC, TDS, F, Cl, HCO3, SO4, NO3, Ca, Mg, Na and K. In general, Ca, Na, Mg, HCO3 and Cl dominate, except in samples from mining areas which have higher concentration of SO4. Water chemistry of the area reflects continental weathering, aided by mining and other anthropogenic impacts. Limitingm groundwater use for domestic purposes are contents of TDS, F, Cl, SO4, NO3 and TH that exceed the desirable limits in water collected from mining and urban areas. The calculated values of SAR, RSC and %Na indicate well to permissible use of water for irrigation. High salinity, %Na, Mg-hazard and RSC values at some sites limit use for agricultural purposes.

4. STUDY AREA

Preliminary investigations were carried out for assessing water quality parameters in an abandoned and active opencast limestone and dolomite quarry (Mine-A). The location of 4 water sampling points are given in Fig. 1.The details of the sample collected are as presented in Table 1.

Table 1: Water Samples with their Respective Locations and Identity (Date: 21.1.13)

	Sl. No.	**Samp le**	**Sl. No.**	**Sample**		**Sa m**	
Sl. No.		**Id**	**Location**	**Id**	**Sample Name**	**I**	
1	1	GP abandoned lime stone1		W1	W1	W	
		mine(Mine-A)					
	4			W4			
2		GP working limestone			W2		
		mine(Mine-A)					
3		PP abandoned dolomite			W3		
		mine(Mine-A)					
4		PP working dolomite mine			W4		
		(Mine- A)					

Figure 1: **Water sampling points at Mine-A**

EXPERIMENTAL METHODOLOGY

4.1 WATER QUALITY ANALYSIS

Water quality is physical, chemical and biological characteristics of water. The representative water samples(4) were collected from the different areas(Working & Abandoned sections) of Mine-A limestone and dolomite quarry and tested for various physical, chemical, metallic and organic parameters that included determination of turbidity (23-32 NTU), conductivity, TDS, iron, chromium, Zn ,pH, hardness, ammonia, nitrate, sulphate, phenol, fluoride, phosphate and organic parameters of importance such as dissolved oxygen, bio-chemical oxygen demand and chemical oxygen demand. The sampling and analysis of different water quality parameters were carried out as per standard methods of analysis of water quality (BIS and NEERI Guidelines)

5. RESULTS AND DISCUSSION

5.1 Water Quality Monitoring Results

All the water samples from the Mine-A were monitored and the results are in the Table 2. Variation of different water quality parameters were plotted in Figs. 2.1 to 2.13.

Turbidity

All the samples collected were having more turbidity than that of the standard. This indicates that the sources may be directly affected by erosion and run off materials from mining operation periodically.

Electrical Conductivity

The electrical conductivity of all the water samples were satisfactory.

Total Suspended Solids and Total Dissolved Solids

Total suspended solids and total dissolved solids are compared to maximum values in the effluent of the same as provided in Schedule VI of Environment (protection) rule, 1986 (EP, 1986) and maximum permissible limit of BIS. From Figures 2.3 and 2.4 it is quite clear that all the samples have total suspended and total dissolved solids within the standards.

Dissolved Oxygen and Chemical Oxygen Demand

The dissolved oxygen in the water is greater than then it needed in the water .Figure 2.6 shows the chemical oxygen demand of the different water samples and compared them with the standard value. It is evident from the figure that all of the water samples have less COD than the maximum permissible value. Which implies all samples are deficient in organic matter or not equivalent to organic matter that can be oxidized by strong agents.

pH and Alkalinity

The pH values of water samples were within prescribed range. All the water samples are little basic in the nature. And the alkalinity of the samples were not high and within the standards.

Chloride, Nitrate and Sulphate

All the three parameters were within the permissible limits.

Hardness

Total hardness, calcium hardness and magnesium hardness of different samples was analyzed. The total hardness was within the limit but the calcium and magnesium hardness of all the samples were greater than the permissible limit. Hardness of water can interpreted that water as moderate hard.

Metal toxicity

The water contained little Fe. However metals such as Cu, Pb, Mn and Zn were absent in all the samples.

Table 2. Water Quality Monitoring Results

PARAMETERS	W1	W2	W3	W 4	STANDARD (B1S:10500,1991)	Max value effluent BIS:2490(Part I) - 1981
pH	7.17	7.43	7.68	8.17	**6.5-8.5**	**5.5-9**
E. Conductivity (µS/cm)	136	192	199	200	**300**	**-**
DO (mg/L)	6.64	6.47	6.72	7.1	**5**	**5**
COD (mg/L)	115.2	114.04	114.44	113.86	**250**	**250**
TDS (mg/L)	433	471	422	384	**2000**	**2100**
Total suspended solids	76	72	74	69	**100**	**100**
Hardness (mg/L)	158	157	159	154	**300**	**600**
Tubidity (NTU)	26	23	32	27	**10**	**10**
Alkalinity (mg/L)	138	136	142	131	**200**	**500**
Chloride (mg/L)	94.4	92.38	56	50.4	**250**	**1000**
Nitrate (mg/L)	5	4.65	3.39	3.25	**10**	**10**

Sulphate (mg/L)	74.2	72.87	67.26	62.25	**150**	**400**
Calcium (mg/L)	102	101	98	100	**75**	**-**
Magnesium (mg/L)	56	56	61	54	**30**	**-**
Sodium (mg/L)	15.35	17.25	12.64	17.21	**-**	**-**
Potasium (mg/L)	1.42	1.32	1.01	1.64	**-**	**-**
Iron (mg/L)	0.27	0.23	0.37	0.16	**1**	**3**
Copper (mg/L)	NIL	NIL	NIL	NIL	**0.05**	**1.5**
Manganese (mg/L)	NIL	NIL	NIL	NIL	**0.1**	**0.3**
Lead (mg/L)	NIL	NIL	NIL	NIL	**0.5**	**0.1**
Zinc (mg/L)	NIL	NIL	NIL	NIL	**5**	**15**

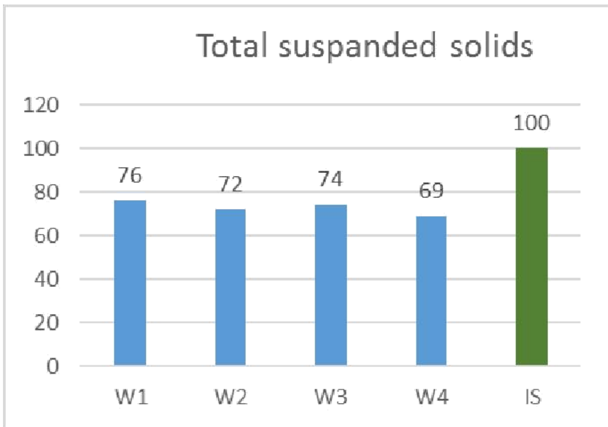


Figure 2.1 Turbidity of water samples

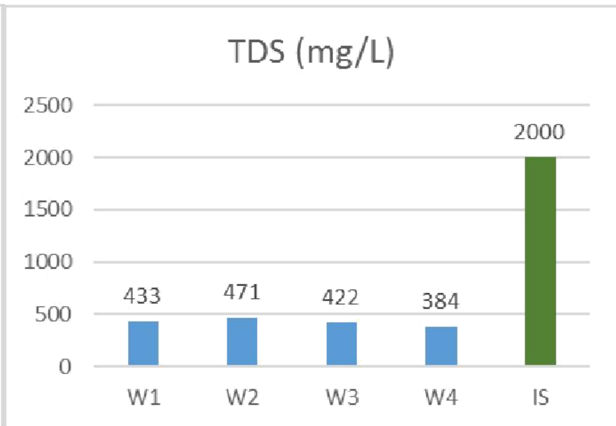


Figure 2.2 E. Conductivity of water samples

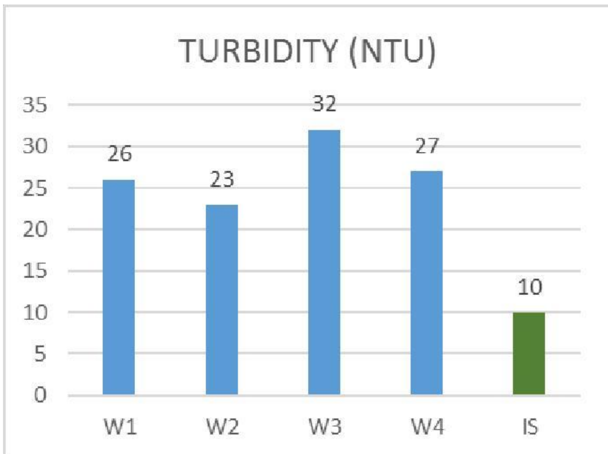


Figure 2.3 TSS of water samples (mg/L)

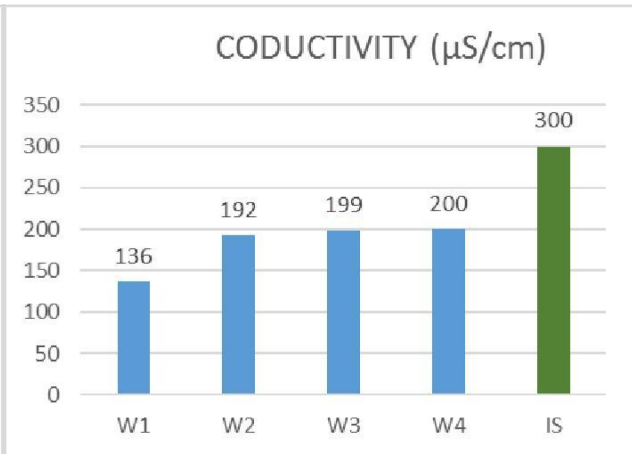


Figure 2.4 TDS of water samples

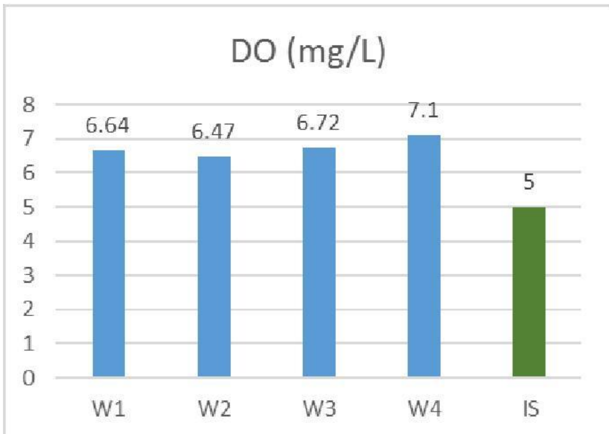


Figure 2.5 DO of water samples.

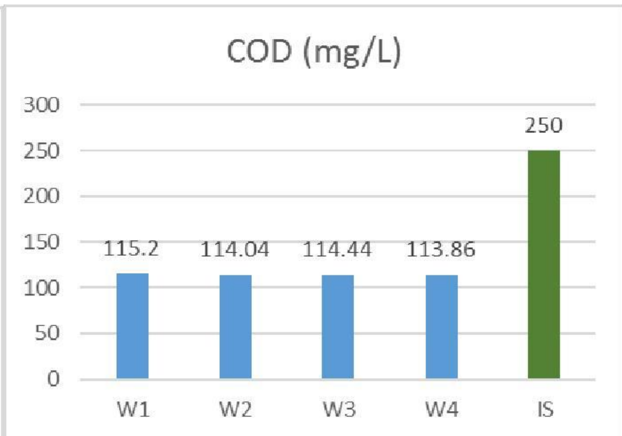
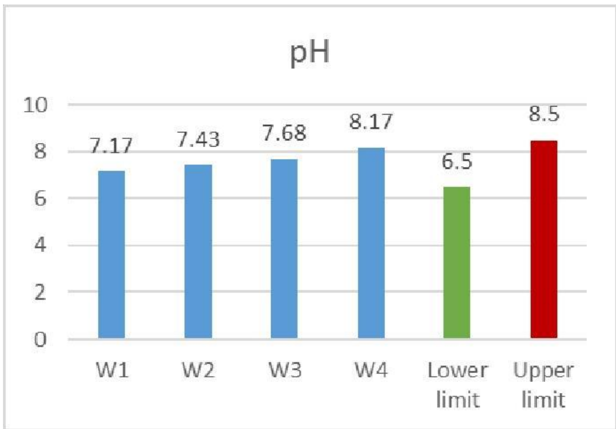


Figure 2.6 COD of water samples



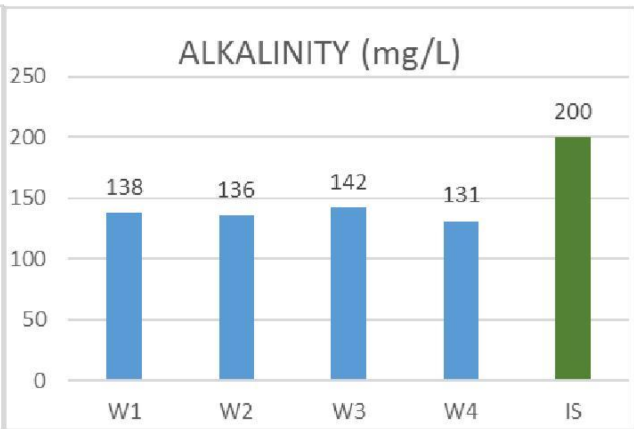
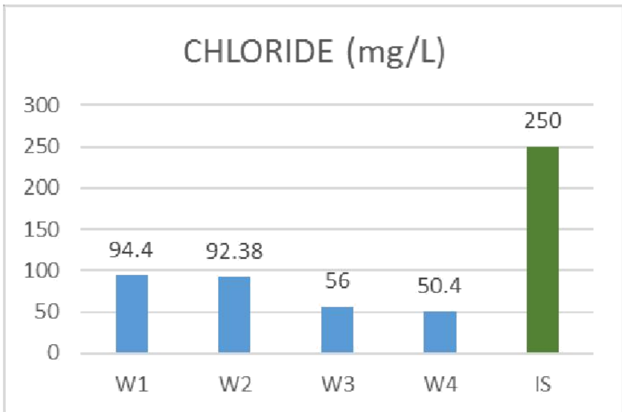


Figure 2.7 pH content of water samples

Figure 2.8 Alkalinity of water samples



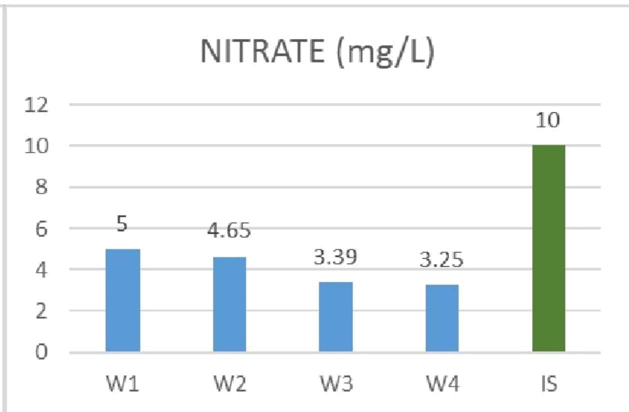
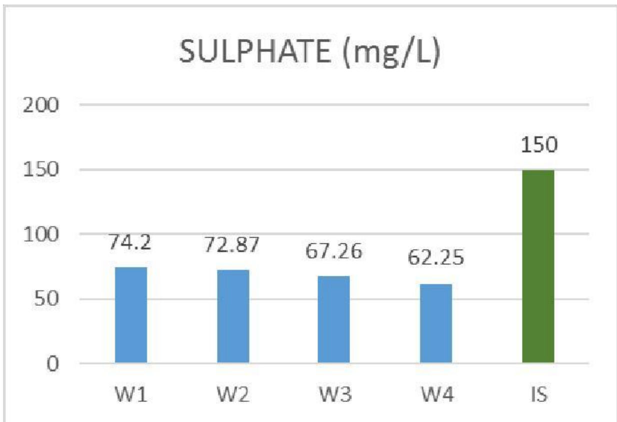


Figure 2.9 Chloride content of water samples

Figure 2.10 Nitrate content of water samples



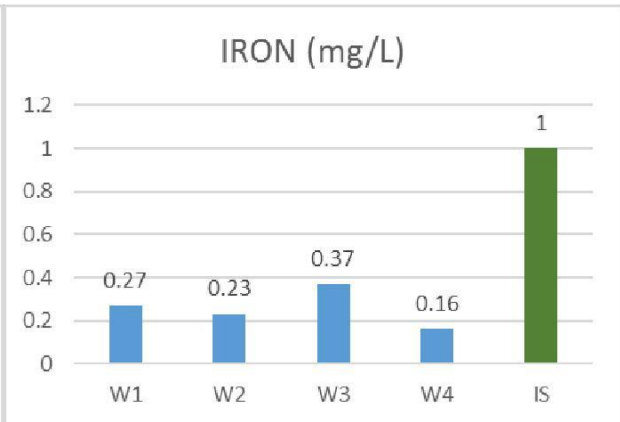


Figure 2.11 Sulphate content of water samples

Figure 2.12 Iron content of water samples

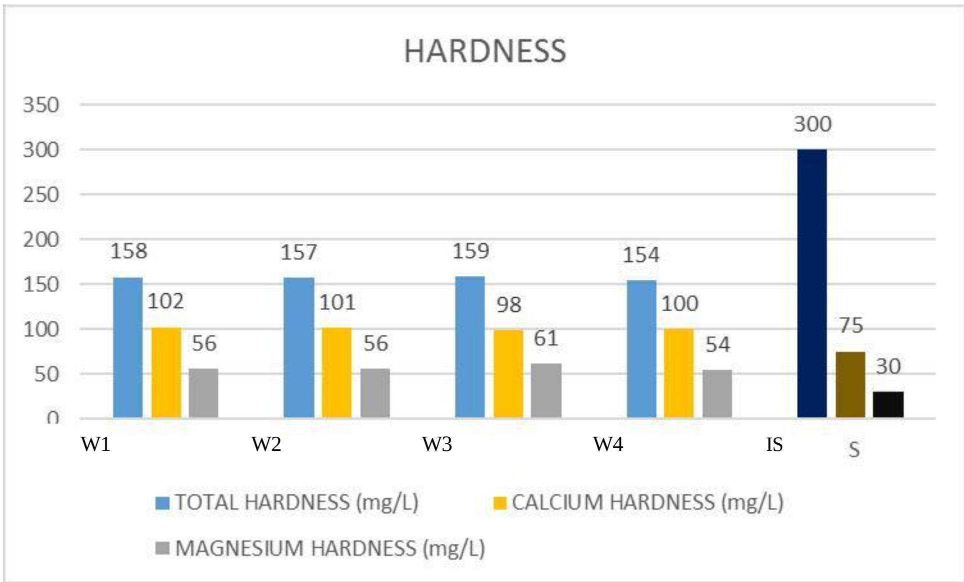


Figure 2.13 Total Calcium and Magnesium Hardness of Different Water Samples

6. CONCLUSION

All the water samples were analyzed for mentioned water quality parameters and it was found that the overall quality of the water is good and the parameters like turbidity (23-32 NTU) and calcium (98-102 mg/L) and magnesium hardness (54-61 mg/L) were slightly greater than the permissible water quality norms. Suitable prevention and treatment of water may be carried out before making suitable utilization of abandoned mine water for different end use as prescribed by Central Pollution Control Board, New Delhi.

7. REFERENCES

1. "Principle of Environmental Impact Assessment Best Practice." International Association for Impact Assessment". 1999.
2. Holder, J., (2004), Environmental Assessment: The Regulation of Decision Making, Oxford University Press, New York; For a comparative discussion of the elements of various domestic EIA systems,
3. Jay, S., Jones, C., Slinn, P., Wood, C., (2007), Environmental Impact Assessment: Retrospect and Prospect, Environmental Impact Assessment Review 27: 287-300
4. Lenzen M., Murray, S., Korte, B., Dey, C., 2003, Environmental Impact Assessment Including Indirect Effects – A case study using input-output analysis, Environmental Impact Assessment Review, 23, pp. 263-282
5. Shepherd. A., Ortolano L., (1996), Strategic Environmental Assessment for Sustainable Urban Development, Environmental Impact Assessment Review, 16, pp. 321-335
6. Abrahim G.M.S. and Parker R.J., (2008), "Assessment of Heavy Metal Enrichment Factors and The Degree of Contamination in Marine Sediments from Tamaki Estuary, Auckland, New Zealand", Environ Monit Assess 136, Springer Science, Pp- 227-238.
7. American Public Health Association (APHA),1985, Standards Methods for Examination of Water and Wastewater, 16th Edition, United States of America, Baltimore, Maryland.
8. Bhuiyan Md. A.H., Islam M.A., Dampare S.D., Parvez L, Suzuki S., 2010 , "Evaluation of Hazardous Metal Pollution in Irrigation and Drinking Water Systems in The Vicinity of a Coal Mine Area of North-Western Bangladesh", Journal of Hazardous Materials 179, Elsevier, pp-1065–1077.
9. Backman B., Bodis D., Lahermo P., Rapant S., Tarvainen T., (1997) "Application of A Groundwater Contamination Index in Finland and Slovakia", Environmental Geology, 36, Pp.55–64
10. Chen A, Lin C, Lu W, Ma Y, Li J, Zhu J, 2007, "Well Water Contaminated by Acidic Mine Water from The Dabaoshan Mine, South China: Chemistry and Toxicity", Chemosphere 70, Elsevier, pp-248–255. Roy, M. P., Roy, S. K. and Singh, Dr. P. K., 2003, "Impact of Mining on Environment – An Appraisal", the Indian Mining and Engineering Journal, Volume 42, no. 11-12.
11. Lambert D.C., McDonough K., Dzombak D.A., 2004,"Long-term Changes In Quality of Discharge Water from Abandoned Underground Coal Mines in Uniontown Syncline, Fayette County, PA, USA", Water Research 38, Elsevier, pp.- 277–288.
12. Ghose M K, 1989, "Land Reclamation and Protection of Environment from The Effect of Coal Mining Operation. Mine tech", 10 (5), pp-35-39.
13. James, D.W., R.J. Hanks, and J.J. Jurinak. 1982. "Modern Irrigated Soils". John Wiley & Sons, New York.
14. Pierzynski, G.M., J.T. Sims, and G.F. Vance. 1994. "Soils and Environmental Quality". Lewis Publ., Boca Raton, FL.