Evaluation of water quality in an intense iron ore mining watershed in Goa

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Abstract -

Nearly 20 percent of the geographical area of Goa is under mining. The open cast mining for iron ore extraction is generally carried out below the water table thereby interacting with the groundwater regime. In the present study attempts have been made to evaluate the status of water quality in one of the intense mining watersheds in Goa. Both surface and groundwater samples were collected and analyzed. In total 24 water quality monitoring stations were established of which 20 stations represent the groundwater and balance 4 stations represent the surface water quality. During the study period water samples were collected during pre-monsoon (May) and post monsoon (November) periods. The analysis were carried out as per IS: 2490 and IS: 10500 standards. Parameters such as pH, DO, Temperature, conductivity and TDS were measured in the field using potable field kits.

The results indicate that the physical, biological and chemical parameters of water from all the sources monitored during study period are not exceeding the prescribed upper limits for drinking use. It is seen that the TDS values slightly increase from post monsoon to pre-monsoon due to summer season. Incidentally the concentrations of iron and manganese are also well within the prescribed upper limits for drinking water. The groundwater pH is slightly acidic in nature.

Key words: Mining, Goa, water quality.

Introduction:

A complex and interrelated series of modifications to natural water quality is created by the diversity of human activities impinging on the hydrologic cycle. It is well recognized that the quality is just as important as its quantity. Pollution can impair the use of water and can create hazards to public health and environment through toxicity and diseases. Among several human activities mining is one which can adversely affect both surface water as well as groundwater quality. In the present study an attempt has been made to assess the ground water and surface water quality in an area where intense open cast iron ore mining activity is taking place in north Goa.

The area is covered by open cast iron ore mining leases often working below water table conditions. It is feared that the mining below water table could have affected the groundwater quality in the area. Therefore is indented in this study to get first hand information of the groundwater quality status so that the possible sources of water contamination and nature of contaminants can be detected for remediation.

The present study area falls in north Goa district located on northern bank of River Mandovi. The area is covered in toposheet no 48E/14/SE (1990-91) and 48I/2/SW (1998-99) of 1:25000 scale having an area of 30 km^2 between latitudes 15^0 28$'$ 00$''$ to 15^0 32$'$ 30$''$ and longitudes 74^0 00$'$ 00$''$ to 74^0 04$'$ 40$''$. The main villages that fall in the area include Velguem and Surla. The location map of the study area is given in Fig.1.

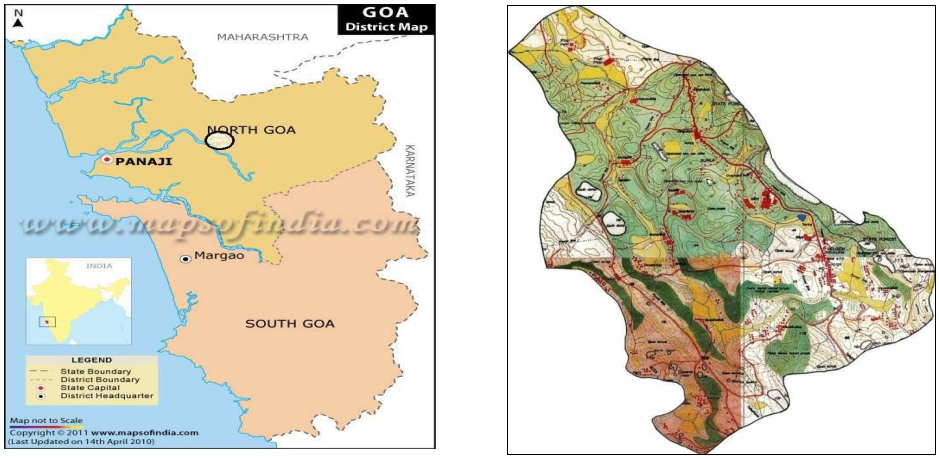

Fig.1: Location map of the study area; watershed boundary is shown on Google image

high hills ranging in elevation of up to 180m above msl the lowest ground elevation in the western part is about 10m above msl. The slopes of these hills are generally vegetated and the plain areas are covered by settlements and paddy fields. The iron ore mining is confined to high ridges in the area. The linear ridge extending from southwest to north east direction in the southern part of the study area act as a barrier between Mandovi River and the rest of this watershed. The land use map is shown in Fig. 2. In order to visualize the topography three dimensional models has been prepared using the ground elevations from survey of India topographic map. The 3D terrain map so prepared is given in Fig.3A. The watershed boundary of the study area is shown marked on the satellite image at Fig.3B.

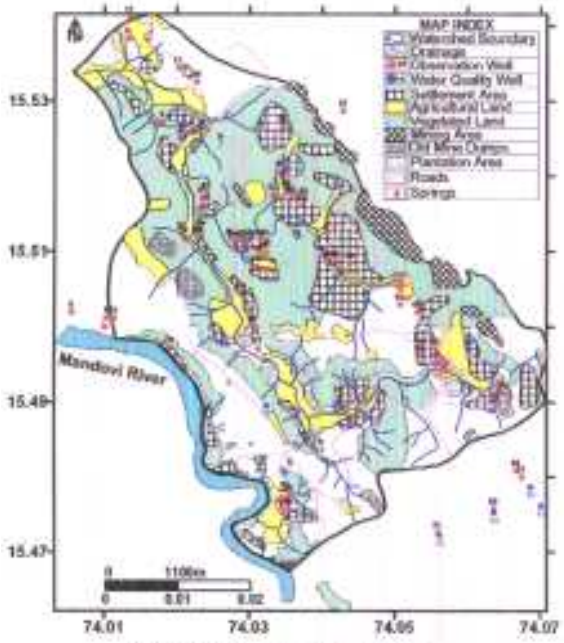

Fig.2: Various land uses in the study area

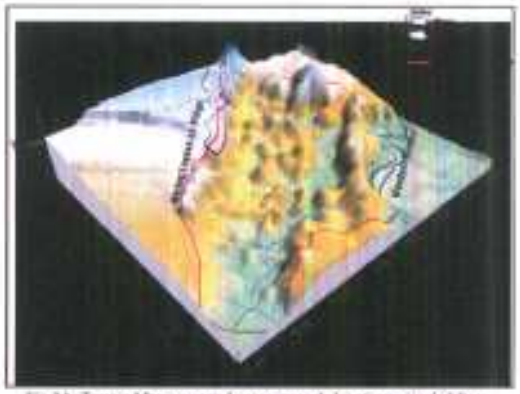

Fig.3A: Terrain Map generated using ground elevations sampled from topographical map of SOI

Fig.3B: Satellite image of the study area watershed

Material and Methodology

The required base map of the area was prepared from the Survey of India toposheet and then this was marked on the Google image to derive the ground elevations. The groundwater sample points were identified at 20 locations and samples were collected from each of these well and subjected to various analysis using standard methods. The TDS, Ec & pH of the water were measured in the field using portable instruments. The well locations used for sampling are shown plotted in Fig.4.

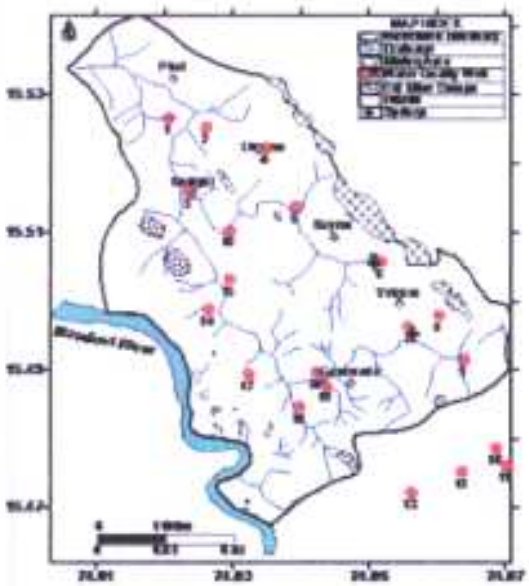

Fig (4). Location of groundwater sampling points

Results and Discussions

The water quality data collected from the field and analyzed in the laboratory are used in assessing the status of the groundwater quality in the study area. The data of the analysis is given respectively in Tables (1) and (2) for pre monsoon and post monsoon for groundwater and Table (3) for surface water. As seen from the data the TDS concentrations of groundwater are moderate generally less than 200 ppm indicating low concentrations of dissolved minerals. The spatial distribution of the TDS values measured during pre and post monsoon seasons are shown in Figs. (5(a)) & (5(b)) respectively. It is seen from the map that the TDS values are well within the prescribed limits for drinking water (1000 ppm) and are not varying significantly with season indicating low levels of mineral dissolution in the area.

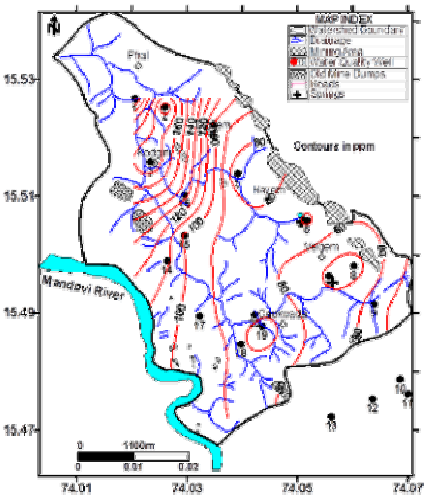

Fig (5(b)).Variation of TDS during post monsoon period

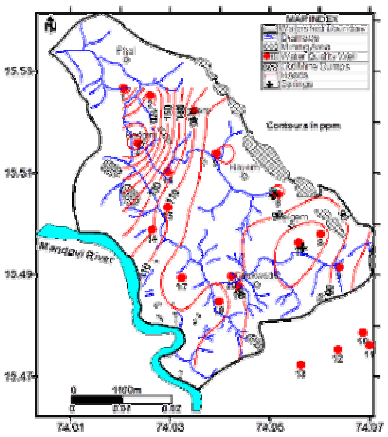

Fig (5(a)) Variation of TDS during pre monsoon period

Parameter	Sample numbers (all units except pH are in mg/l)																			
	1	2	3	4	5	7	8	9	10	11	12	13	14	15	17	18	19	20	21	22
pH	7.2	6.4	7.2	7.7	6.5	6.2	7.5	6.4	7.5	7.4	7.2	6.4	6.8	5.9	5.7	6.4	6.9	7.5	6.8	7.4
DO	6.4	5.4	6.0	6.2	6.2	5.4	6.2	6.1	5.8	6.4	4.6	4.4	5.9	5.6	6.7	5.4	4.8	6.6	6.2	6.2
TDS	129	176	198	105	89	102	72	76	95	108	178	120	74	121	108	125	89	108	88	98
Alkalinity	24	29	36	20	16	19	24	10	12	12	22	14	8	10	7	24	18	12	12	10
TH	30	90	80	40	8	10	6	8	10	20	80	25	8	6	6	30	20	14	30	10
Nitrate	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Chloride	12	16	14	18	15	22	16	14	18	24	20	22	18	30	16	18	14	15	14	20
Sulphate	8	10	4	4	10	12	8	6	4	6	8	10	10	8	4	12	10	4	6	8
Sodium	8	8	6	8	6	10	6	8	8	6	10	12	8	10	12	12	6	10	10	8
Potassium	2	1	2	1	2	1	2	2	1	1	2	3	2	2	3	2	4	1	2	1
Calcium	6	30	28	14	6	4	3	4	3	8	40	16	4	4	1	22	18	6	14	6
Magnesium	3	8	10	6	2	2	1	2	1	4	6	4	2	2	2	6	8	4	3	1
Iron as Fe	0.16	0.26	0.13	0.08	0.16	0.26	0.19	0.10	0.14	0.18	0.21	0.15	0.24	0.18	0.17	0.14	0.18	0.14	0.16	0.10
Fluoride	0.40	0.62	0.36	0.29	0.17	0.12	0.27	0.21	0.38	0.24	0.27	0.22	0.51	0.59	0.28	0.25	0.26	0.48	0.28	0.33
Boron	0.15	0.15	0.07	0.16	0.08	0.15	0.14	0.17	0.14	0.04	0.13	0.15	0.14	0.07	0.07	0.09	0.01	0.09	0.17	0.18

Table-(1): Groundwater quality data of Velguem-Surla-Pale mining area (Pre monsoon; May)
Note: Cd, Cr, Mn, Zn, Cu, Pb, Hg, Se, As and Cn are found to be below detection limits

Parameter	Sample numbers (all units except pH are in mg/l)																			
	1	2	3	4	5	7	8	9	10	11	12	13	14	15	17	18	19	20	21	22
pH	7.0	6.8	7.8	7.1	6.1	6.4	7.1	6.8	7.2	7.0	7.0	6.8	6.2	6.4	6.2	6.9	6.8	7.4	7.2	7.1
DO	6.2	5.9	6.5	6.4	6.8	5.2	6.4	5.8	5.4	6.1	4.1	3.5	5.4	5.8	6.0	5.2	4.1	6.4	5.8	6.4
TDS	120	188	180	98	72	92	68	65	86	98	186	110	68	112	98	135	94	89	98	82
Alkalinity	28	32	34	22	12	18	22	12	14	16	28	15	7	12	9	26	16	14	16	15
TH	40	80	90	30	10	8	4	10	8	30	70	30	6	4	4	40	30	12	40	8
Nitrate	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Chloride	15	18	16	14	17	26	14	13	19	20	23	18	15	40	22	16	18	19	17	24
Sulphate	10	8	5	5	8	18	5	7	6	6	10	12	8	6	6	8	6	5	8	6
Sodium	6	10	4	6	8	8	8	6	10	4	12	8	6	12	10	10	8	10	8	10
Potassium	1	2	1	2	1	2	2	1	2	2	3	2	1	3	2	3	3	2	2	2
Calcium	8	20	24	12	4	3	2	4	4	10	30	18	2	2	2	20	16	4	16	4
Magnesium	4	10	12	4	1	1	1	2	2	3	4	3	1	1	1	4	6	2	4	2
Iron as Fe	0.19	0.21	0.10	0.05	0.12	0.20	0.18	0.08	0.19	0.11	0.26	0.14	0.21	0.14	0.18	0.12	0.16	0.11	0.18	0.09
Fluoride	0.48	0.55	0.44	0.25	0.29	0.14	0.26	0.24	0.45	0.21	0.24	0.28	0.44	0.61	0.25	0.21	0.17	0.42	0.26	0.34
Boron	0.11	0.10	0.09	0.12	0.04	0.16	0.11	0.12	0.11	0.03	0.13	0.10	0.09	0.08	0.02	0.12	0.18	0.14	0.12	0.14

Table-(2): Groundwater quality data of Velguem-Surla-Pale mining area (Post monsoon; November)
Note: Cd, Cr, Mn, Zn, Cu, Pb, Hg, Se, As and Cn are found to be below detection limits

Parameter	Sample numbers (all units except pH are in mg/l)							
	Pre monsoon				Post monsoon			
	1SW	2SW	3SW	4SW	1SW	2SW	3SW	4SW
pH	5.4	6.2	6.4	7.4	5.7	6.8	6.6	6.2
DO	5.4	5.0	5.6	6.4	5.1	5.2	5.9	6.2
TDS	110	248	128	98	105	269	122	89
Alkalinity	6	42	18	4	5	53	16	2
TH	8	90	6	8	6	110	8	10
Nitrate	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Chloride	16	12	16	14	18	14	18	19
Sulphate	10	6	12	10	8	5	18	12
Sodium	8	10	10	8	10	12	8	6
Potassium	2	3	3	2	3	4	2	1
Calcium	4	30	4	6	3	40	2	4
Magnesium	1	16	2	1	2	20	1	2
Iron as Fe	0.28	0.24	0.18	0.24	0.35	0.20	0.15	0.22
Fluoride	0.21	0.38	0.14	0.24	0.29	0.42	0.19	0.26
Boron	0.12	0.18	0.16	0.24	0.11	0.21	0.14	0.21

Table-(3): Surface water quality data of Velguem-Surla-Pale mining area
Note: Cd, Cr, Mn, Zn, Cu, Pb, Hg, Se, As and Cn are found to be below detection limits

The pH of groundwater is generally seen to be less than neutral. The pH variation during pre and post monsoon seasons at different sampling locations is shown in Fig.6. It is seen from the figure that the groundwater are little acidic and hence corrosive in nature. The pH does significantly change from season to season. The low pH of groundwater could be the result of one or all of the following geochemical reactions;

1) Nitric acid (HNO_3) formed due to organic nitrate in soil zone release H^+ ions which reduce pH (high H^+ low pH)
2) Non availability of Ca and Mg in abundance which are buffering agents in moderate pH, the pH remains low; the Ca and Mg contents in groundwater are very low in Goa.
3) Manganese oxidation : $O_2 + 2Mn^{+2} + 2H_2O = 2MnO_2(s) + \mathbf{4H^+}$
4) The reaction of iron with water releases 8H+ which definitely lowers the pH

$4Fe^{2+} + O_2 + 6H_2O \rightarrow$ 4FeOOH + $\mathbf{8H^+}$
(Ferrous ions) (Solid iron hydroxide) (Lowers pH)

This also explains that the groundwater has low iron content in the mining areas.

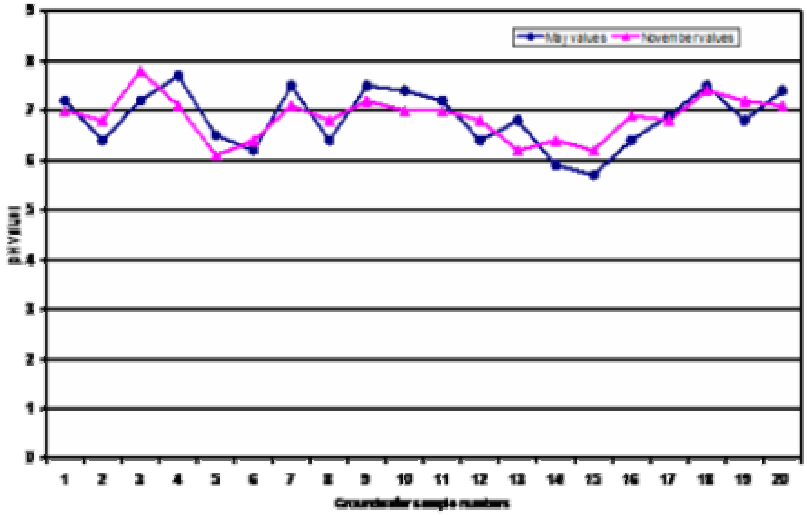

Fig (6). Variation of pH of groundwater during different seasons

The iron content in groundwater is show plotted in Fig (7). The data indicate that the iron in groundwater is well within the prescribed limits for drinking water. Similarly the iron concentration does not significantly vary from season to season indicating low level dissolution of iron in water.

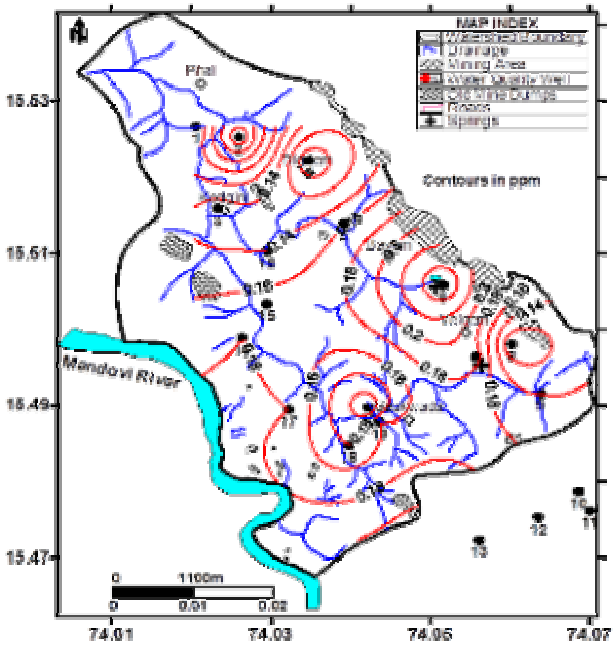

Fig (7). Iron content in groundwater during May