Mine Water and the Environment (2007) 26: 119–123 © IMWA Springer-Verlag 2007

Technical Communication

Effects of a Barite Mine on Ground Water Quality in Andhra Pradesh, India

Sama Suresh[1], Nirugatti Dinakar[1], T.N.V.K.V. Prasad[2], P. C. Nagajyothi[1], Thoti Damodharam[1], and Arveti Nagaraju[3]

[1]Env Sciences Dept, Sri Venkateswara Univ, Tirupati 517 502, Andhra Pradesh, India; [2]Regional Agricultural Research Station, Acharya N.G. Ranga Agricultural Univ, Tirupati 517 502, Andhra Pradesh, India; [3]Geology Dept, Sri Venkateswara Univ, Tirupati 517 502, Andhra Pradesh, India; corresponding author's e-mail: thotidamodharam@yahoo.co.in

Submitted December 21, 2006; accepted January 8, 2007

Abstract. An investigation was undertaken to determine the effects of a large barite mining operation on local ground water quality near Mangampeta, Andhra Pradesh, India. Water samples were collected from drinking water wells in the mining and adjacent regions. The drinking water in the mining region had sulphate concentrations that ranged from 211 to 589 mg/L, compared to sulphate concentrations of 25 mg/L or less in the non-mined areas. The natural existence of barite and the widespread mine waste dumps at Mangampeta are believed to be responsible for the higher levels of sulphate in the ground water.

Key words: aquifer characteristics; barite mines; India; sulphate

Introduction

The mining and metallurgical processing of barite ($BaSO_4$) ores generates vast quantities of mine rock and mine tailings. Barite has been mined near the village of Mangampeta, in Andhra Pradesh, India, since 1975. The site is the largest barite deposit in the world with an estimated reserve of over 65 million tons of barite, representing about 87% of the country's reserves and over 25% of the world's known reserves (Subba Rao 2004). The natural occurrence of barite at Mangampeta and its commercial exploitation potentially threatens local ground water resources due to the leachate from the waste. Due to the lack of surface water, the inhabitants at Mangampeta depend on ground water resources for drinking and agriculture. Surprisingly little attention has been given to this issue.

The natural chemistry of ground water is controlled largely by the dissolution of the geologic materials through which the water flows. Contaminants can enter ground water by a variety of means, including sources at the ground surface. The major processes that influence the migration of contaminants include advection, dispersion, physical filtering, sorption, precipitation, and biological transformation. The dominant processes in a particular region depend on the geological and geochemical conditions, as well as the chemical and biological characteristics of the contaminant. Mine waste can generate elevated levels of sulphate, metals, and acidity. Unless mine waste sites are protected from oxidation and metal release, these sites represent a source of serious contamination to ground water and aquatic systems for potentially hundreds to thousands of years.

Though the probable risk of ground water contamination has been recognized, researchers have focused on the geological aspects of the Mangampeta barite mining region rather than its environmental aspects (Basu 1997; Kurien et al. 1977; Neelakantam 1987; Viswanath and Sastry 1983). This study represents an initial effort to characterize the extent and nature of contamination in ground water, as it potentially relates to the barite mining and processing.

Study Area

The Andhra Pradesh Mineral Development Corporation (APMDC) has been involved in the exploration and commercial exploitation of barite at the village of Mangampeta since 1975. The barite deposit extends over 160.691 ha in the Kadapa district in Andhra Pradesh, which is in southeastern India (N14°01'; 79°19' E). The leasehold area is a gently undulating plain with an open mine pit that is 250 m long, 110 to 170 m wide, and about 60 m deep. The working pit in the area is partly filled with seepage water. There are many small reservoirs within 5 km of the leasehold, which have resulted from impounding several rills rising from the adjacent hills.

Materials and Methods

Field investigations, sampling, and analysis were carried out during February and March 2005. Thirty water samples were collected from drinking wells

located in villages in mined (1-15) and non-mined areas (16-30) in one L polyethylene containers. The samples were collected directly from the wells, as drinking water is routinely collected by the inhabitants, without pre-sampling bailing or pumping. During collection, each sample bottle was thoroughly rinsed with the ground water sample being collected. The water samples were immediately transferred to the experimental laboratory and were kept refrigerated until analyzed. Electrical conductivity (EC) and pH were measured at the point of collection using an Elico micro-based pH and conductivity meter. The concentration of total dissolved solids (TDS) was calculated by multiplying the electrical conductivity at 25°C by a factor of 0.64 (Hem 1985), and thus only represents an approximate value. Total hardness, total alkalinity, calcium, and chloride were measured by volumetric analysis; sulphate concentrations were analyzed using a Lovibond PC Spectrophotometer (SN 100537, Germany); carbonates and bicarbonates were calculated from total alkalinity (APHA 1989; Brown et al 1970; Hem 1985; Indian Standards Institute 1983; Rainwater and Thatcher 1960). The obtained results were compared with WHO standards

Results and Discussions

The analytical results are listed in Table 1. The water samples were colourless. After storage in closed bottles for a few days, a strong chemical odour was detectable in some of the ground water samples from the mined area.

The obtained ground water quality data was subjected to multiple regression analysis using MSTAT software, which revealed that EC, hardness, and bicarbonates

Table 1. Analysis of water samples in mg/L, except for pH and electrical conductivity (EC) (µS/cm); samples 1-15 are from the mining region while 16 – 30 are from non-mined areas. TDS values were calculated based on the EC values and can only be considered approximations.

Sample #	pH	EC	TDS	Hardness	Alkalinity	Ca	Mg	CO_3	HCO_3	Cl	SO_4
1	7.55	1259	806	452	146	20	96	10	140	133	340
2	7.67	1035	662	396	232	34	54	14	223	114	211
3	8.00	1514	969	580	159	49	109	12	160	124	474
4	7.45	1292	827	475	185	24	98	11	177	125	336
5	8.08	1286	823	473	148	11	106	9	152	117	374
6	7.39	1308	837	477	168	33	94	13	173	115	378
7	7.44	1327	849	475	164	36	92	11	164	128	380
8	7.54	1273	815	456	148	20	96	9	149	137	342
9	7.70	1024	655	392	204	36	64	14	197	114	216
10	7.47	1277	817	452	158	23	95	9	155	124	342
11	8.10	1689	1081	669	143	49	132	15	148	128	558
12	8.12	1736	1111	676	149	46	139	7	154	126	589
13	7.88	1239	793	454	174	22	96	10	180	129	326
14	8.00	1235	790	405	156	19	85	13	156	132	318
15	7.72	1610	1030	625	168	50	120	9	172	115	509
16	7.40	951	609	422	500	30	66	10	419	68	15
17	7.33	1326	849	348	412	50	53	29	404	72	23
18	7.42	804	515	324	289	47	46	26	235	91	14
19	7.34	1025	656	461	522	25	75	10	440	85	19
20	7.21	1250	800	678	657	20	127	15	520	85	25
21	7.55	1241	794	629	606	21	108	12	550	78	14
22	7.30	1200	768	688	670	18	91	18	536	75	23
23	7.87	809	518	483	512	25	60	12	350	47	17
24	7.16	930	595	386	391	34	49	31	369	83	15
25	7.33	880	563	360	339	32	44	45	302	72	20
26	7.43	1186	759	443	422	50	53	29	404	69	22
27	7.83	990	634	392	435	28	65	14	416	82	14
28	7.25	1284	822	571	496	20	103	22	440	209	19
29	7.62	1228	786	660	666	21	107	20	445	154	16
30	7.40	946	605	353	321	29	44	22	400	84	20

were directly related to sulphate concentration. In addition, alkalinity, calcium, magnesium, carbonates, and chlorides were indirectly related to sulphate concentration. The correlation coefficient, $R^2 = 0.993$ indicates that there is a 99% positive association between the sulphate levels and EC, hardness, and bicarbonate concentrations.

The range of pH obtained in the mining province was between 7.39 and 8.12, whereas in the non-mining region, it was between 7.16 and 7.87. All the ground water samples were alkaline, principally due to the high carbonate and bicarbonate concentrations. The important geological formations in this area are quartzites, carbonaceous tuff, and dolomites, which explains the alkaline pH.

The ground water samples from the mining region was more mineralized, with EC values between 1024 and 1736 µS/cm, than those from the non-mining region, which ranged between 804 and 1326 µS/cm. Calculated TDS values for samples from the mining area ranged between 655 and 1111 mg/L, whereas in the non-mining region, it ranged between 515 and 849 mg/L. An aesthetic objective of 500 mg/L has been established for total solids in drinking water (Indian Standards 10500 1991).

At higher levels, excessive hardness, mineral deposition, and corrosion can occur (Sawyer and McCarty 1967). High levels in drinking water can cause objectionable tastes and have a laxative effect (Kumaraswamy 1991). Based on the approximate TDS levels, the palatability of drinking water has been rated by Bruvold and Ongerth (1969) (Table 2). Based solely on these ratings, samples 18, 23, 24, and 25 should taste good, samples 1, 2, 4, 5, 6, 7, 8, 9, 10, 13, 14, 16, 19, 20, 21, 22, 26, 27, 29, and 30 should taste fair, and samples 3, 11, 12, and 15 should taste poor.

Some studies have shown inverse relationships between TDS concentrations in drinking water and the incidence of cancer (Burton and Cornhill 1977), coronary heart disease (Schroeder 1960), arteriosclerotic heart disease (Schroeder 1966), and cardiovascular disease (Craun and McCabe 1975; Saner 1974). Total mortality rates were reported to be inversely correlated with TDS levels in drinking water (Craun and McCabe 1975; Crawford et al. 1968). Conversely, an Australian study reported that mortality due to all categories of ischaemic heart disease and acute myocardial infarction was increased in a community with higher levels of soluble solids, calcium, magnesium, sulphate, chloride, fluoride, and total hardness, when compared with a community in which levels were lower (Meyers 1975). An epidemiological study in the former Soviet Union indicated that the average number of cases of inflammation of the gall bladder and gallstones over a five-year period increased with the mean level of dry residue in the ground water (Popov 1970). It should be noted, however, that the number of cases varied greatly from year to year in one district, as did the concentration of dry residue in each district.

Table 2. The effect of total dissolved solids on taste (Bruvold and Ongerth 1969)

Taste rating	TDS concentrations
Excellent	less than 300 mg/L
Good	between 300 and 600 mg/L
Fair	between 600 and 900 mg/L
Poor	between 900 and 1200 mg/L
Unacceptable	greater than 1200 mg/L

The ground water samples from both the mining and non-mining areas had high hardness values. Excess hardness is undesirable, mostly for economic and aesthetic reasons. The National Research Council (1997) reported cardiovascular problems in areas where water has high hardness values.

The ground water alkalinity observed in the mining region ranged between 143 and 232 mg/L and between 289 and 670 mg/L in the non-mining region, reflecting lower carbonate and bicarbonate concentrations in the mining areas. Alkalinity is important because it buffers pH changes that occur naturally during water exchanges in the aquifers.

The range of both the Ca and Mg values were similar in the mining and non-mining areas. Magnesium ions dominated in both, due to the presence of dolomites.

The sulphate concentrations in the mining province ranged between 211 and 589 mg/L, whereas in the non-mining region, it only ranged up to 25 mg/L. The higher sulphate concentrations in the mining region confirm the influence of the barite deposit and associated commercial activity. Dissolved sulphate is stable under oxidizing conditions; however, under reducing conditions, it can be converted to hydrogen sulfide (H2S). Dissolved sulphate can combine with calcium to cause scaling problems in water heaters and boilers. Sulphate is one of the least toxic anions, although relatively high levels (>1000 mg/L) can cause adverse effects in some aquatic species and, at concentrations exceeding 500 to 600 mg/L, it imparts a bitter taste and can cause gastrointestinal problems. For these reasons, the recommended upper limit is 200 mg/L in waters intended for human consumption (WHO 1983).

Conclusions

The barite mining region at Mangampeta has been experiencing environmental and ecological degradation over the last three decades. Inadequate information and inappropriate technology are some of the limiting factors for effective environmental management. Comparing the chemical composition of the ground water of the Mangampeta mining region and the nearby non-mining areas suggest that the mining has caused problematic levels of sulphate.

Reducing sulphate concentrations significantly is not simple, but nonetheless, treatment plants should be set up to treat the mine water and community drinking water supplies to reduce the sulphate levels and avoid further aquifer contamination.

References

APHA (American Public Health Assoc) (1989) Standard Methods for Examination of Water and Wastewater. 17th Edit, WA, WPCF, New York, NY, USA, 422 pp

Basu PK (1997) On Archaean and Proterozoic barite deposits of Cuddapah Basin. Ind Miner 51: 169-178

Bureau Indian Standards 10500 (1991) Specification for Ground Water Quality Standards, New Delhi. Referenced in Kumar MS, Ravindranath S, Water Studies, Centre for Environment Education, Bangalore, Ahmedabad, India

Brown E, Skougstad MW, Fishman MJ (1970) Methods for collection and analysis of water samples for dissolved minerals and gases. Techniques of Water Resources Investigations of the US Geological Survey, Book 5, Ch A-1, p 126-129

Bruvold WH, Ongerth HJ (1969) Taste quality of mineralized water. J Am Water Works Assoc 61: 170-174

Burton AC, Cornhill JF (1977) Correlation of cancer death rates with altitude and with the quality of water supply of the 100 largest cities in the United States. J Toxicol Environ Health 3(3): 465-478

Craun GF, McCabe LI (1975) Problems associated with metals in drinking water. J Am Water Works Assoc 67: 593-599

Crawford M, Gardner MJ, Morris JN (1968) Mortality and hardness of local water supplies. Lancet 1: 827-831

Hem JD (1985) Study and interpretation of chemical characteristics of natural water. USGS Water Supply Paper # 2254, 3rd Edit, US Govt Printing Office, Washington, DC, USA, 263 pp

Indian Standards Institute (1983) Indian standard specifications for drinking water. Indian Standards: 10500, New Delhi, India, 22 pp

Kumarswamy N (1991) An approach towards assessment of dug-well water quality by physico-chemical characteristics - a case study. Poll Res 10(1): 13-20

Kurien T K, Setti D N, Neelakantam S, Suthanandam P, Roy S (1977) Baryte Mineralization and its Origin, Mangampeta, Cuddapah District, Andhra Pradesh. Ind Miner 18: 1-6

Meyers D (1975) Mortality and water hardness. Lancet 1: 398-9

National Research Council (NRC) (1997) Drinking Water and Health. Vol 4, Safe Drinking Water Committees, National Academy Press, Washington DC, USA

Neelakantam S (1987) Mangampeta Barites Deposits, Cuddapah District, Andhra Pradesh. Mem Geol Soc India 6: 429-458

Popov VV (1970) Cholelithiasis and calculi, hardness of drinking water. Gig Sanit 33(6): 416

Rainwater FH, Thatcher LL (1960) Methods for collection and analysis of water samples. USGS Water Supply Paper # 1454, Washington DC, USA, 301 pp

Saner HI (1974) Relationship between trace element content of drinking water and chronic disease. Univ Ill Bull 71(108): 39

Sawyer CN, McCarty PL (1967) Chemistry for Sanitary Engineers. 2nd Edit, McGraw-Hill Series in Sanitary Science and Water Resources Engineering, McGraw-Hill, Toronto, Canada, 405 pp

Schroeder HA (1960) Relation between mortality from cardiovascular disease and treated water supplies. Variation in states and 163 largest municipalities. J Am Med Assoc 172: 1902-1908

Schroeder HA (1966) Municipal drinking water and cardiovascular death rates. J Am Med Assoc 195: 125-129

Subba Rao MV (2004) A case study of mining environmental activities of the Andhra Pradesh Mineral Development Corporation Limited, APMDC, Hyderabad, Andhra Pradesh, India. Unpublished report generated for environmental management capacity building technical assistance project and international training programme, Univ of South Wales, Sydney, Australia

Viswanath K, Sastry AVR (1983) Volcanogenic rocks from Mangampeta Area, Andhra Pradesh. Ind J Earth Sci 10: 142-151

WHO (World Health Organization) (1983) Guidelines to Drinking Water Quality. Geneva, Switzerland, 186 pp