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Magnetic-Radiometric Monitoring of Particulate Pollution from Kudremukh Iron Ore Mines, Karnataka

Kudremukh is the largest mechanised mining project in India. In spite of the steps being taken to arrest particulate pollution, it is feared that the pollution is significant. Using magnetic and radiometric properties of catchment soils, ores and tailings, the relative proportions of naturally weathered and man-made particles in the Bhadra river-bed sediments were estimated. Upstream of the mine and the tailings dam, the river bedload is composed principally of catchment soil materials (>97%). However, downstream of the mine segment the average mine waste component is about 47%. Magnetic methods are simple, rapid, inexpensive and non-destructive and can be employed on a routine basis in the environmental monitoring program at Kudremukh and other mines.

Introduction: Located in the Western Ghats, Kudremukh iron ore mine (13°07' 45"N latitude, 75°15'20"E longitude) is the largest mechanized open-cast mining venture in the country. Iron ore is mined from the upper most segment of the Bhadra river basin. About 50 km downstream of the mines is the Bhadra reservoir which irrigates large tracts of land.

The Bhadra river basin which includes the Kudremukh mine forms a part of southwestern Karnataka. The stratigraphic sequence at Kudremukh consists of Peninsular Gneiss at the base, overlain unconformably by metabasalts and amphibolites, with intercalations of chlorite schists and quartzites, followed by a unit of iron-rich schists with banded magnetite quartzites and succeeded by silicic turbidites that are rich in volcanogenic clasts (Sampat Iyengar, 1912; Drury *et al.* 1983; Ramakrishnan, 1994).

Weathered, soft ore (up to 50 m depth) from Kudremukh is mined with mechanized equipment. The ore is crushed in jaw and gyratory crushers and subsequently in ball mills. Beneficiation is carried out taking advantage of the high specific gravity and ferrimagnetic nature of the ore. The ore concentrate is pumped as slurry through a pipeline to the New Mangalore Port. The tailings are stored in the Lakya dam constructed for this purpose.

The Kudremukh Iron Ore Company Limited has been using sprinklers and carrying out afforestation to minimize particulate pollution arising from its mining operations. But environmentalists fear that because of the large amount of particulates released when the soft ore is stripped, sediment supply to the natural system is on the increase. This, is turn, could lead to an enhanced rate of siltation in the Bhadra reservoir causing a reduction in its water-bearing capacity. Therefore, this study was taken up to quantitatively estimate the particulate pollution of the Bhadra river as a result of mining at Kudremukh.

Rock magnetic techniques were used to achieve the objective because Kudremukh iron ore is magnetite. As this ore mineral is strongly magnetic, its presence, even in small concentrations in river-bed sediments, is easily detected using magnetic methods. The country rocks, on the other hand, are generally magnetically weak. Taking advantage of the contrasting characteristics, the magnetic properties of river-bed sediments were modelled in terms of catchment sources (different types of soil) and man-made sources (ore and tailing particles released because of the mining activity). Although the catchment and man-made sources could be successfully discriminated with magnetic parameters, additional physical properties were useful for quantitative unmixing calculations. Alpha and beta counts of the potential source materials were useful in conjunction with magnetic data. The paired artificial magnetisation and natural radioactivity data provided a clear distinction between the catchment soils and the man-made sources and allowed quantitative estimates of the various components of the river-bed sediments to be made.

Samples and Methodology : Samples of fresh, partially weathered and highly weathered ores from the mine site, tailings from the bed of Lakya dam, surficial soils from different localities and river-bed sediments both upstream and downstream of the mine were collected in October 1991. All samples were stored in polythene bags. Laboratory studies were made after drying the samples overnight at 60°C.

Eleven magnetic measurements, were made; magnetic susceptibility, Anhysteretic Remanent Magnetisation (ARM), Isothermal Remanent Magnetisation (IRM) at 20, 40, 60, 80, 100, 200, 300, 1000 and 2000 milli tesla (mT), and natural alpha and beta activity. The data were used to mathematically unmix the river-bed sediments into the proportions of a) naturally eroding materials, i.e., the soils and river banks, and b) mine waste material of ore, spoil and tailing. We have unmixed the data by a multivariate multiple maximum likelihood calculation and solving the regression relationships for all samples simultaneously. Details of methodology are given by Shankar *et al.* (1994).

Results and Discussion : The dominant magnetic mineral in the Kudremukh samples is magnetite. Its concentration varies from about 0.02% in one soil sample to >50% in the primary ore. Table I gives the median and range of radiometric and magnetic measurements for the a) ore and mine waste, b) soil, and c) river-bed sediments. Susceptibility, ARM and IRMs exhibit similar relationships in the three groups. The highest concentration of magnetite is in the primary ore, followed by the tailings; the soils are the poorest in magnetite. On the contrary, alpha and beta counts are higher in the soils than in the mined material. The magnetic and radiometric properties of the river bedload are all intermediate between the ore and soils, barring a few exceptions.

Table I. Median and ranges of natural radioactivity and artificial magnetisation for Kudremukh samples.

		-- Ores and Mined waste-				----------- Soils ----------				----- River bedload -----			
		N	Median	Min	Max	N	Median	Min	Max	N	Median	Min	Max
Beta	(Counts/ks)	11	1.9	0	10	28	120	17	430	22	50	9	159
Alpha	(Counts/24h)	11	22	6	67	28	808	262	1609	22	340	111	1091
SUSC	(μm3kg-1)	11	78	13	202	28	4.7	0.16	22	22	42	0.7	240
ARM	(mAm2kg-1)	11	10	1.9	23	28	1.1	0.01	8.9	22	3.7	0.2	19
IRM20	(mAm2kg-1)	11	144	17	443	28	6.5	0.08	38	22	51	1.8	217
IRM40	(mAm2kg-1)	11	387	45	1076	28	12	0.09	74	22	122	3.7	496
IRM60	(mAm2kg-1)	11	589	79	1438	28	17	0.11	89	22	178	3.9	759
IRM80	(mAm2kg-1)	11	717	106	1621	28	20	0.12	102	22	218	4.0	899
IRM100	(mAm2kg-1)	11	881	128	1920	28	22	0.12	115	22	256	4.2	1081
IRM200	(mAm2kg-1)	11	1150	185	2408	28	28	0.99	149	22	322	5.7	1329
IRM300	(mAm2kg-1)	11	1182	198	2335	28	31	1.0	159	22	339	7.7	1365
IRM1T	(mAm2kg-1)	11	1239	233	2589	28	35	1.1	172	22	362	14.7	1410
IRM2T	(mAm2kg-1)	11	1256	233	2589	28	36	1.2	173	22	370	14.9	1419

The results obtained from end-member discrimination and unmixing calculations are shown in the form of pi charts (Fig. 1). These depict the proportions of mine waste component in the river bedload samples from 22 locations along the Bhadra river. Errors in the estimates are typically around 5%. The three river bedload samples upstream of the mine site model, as expected, with high catchment components of >97%. As the tailings dam is approached, and near the mine site, the proportion of mine waste component increases. Below the outfall of the mine the average mine waste component models as 47%. Further downstream its proportion varies considerably; this may be ascribed to sorting of sediments during transport and variation in particle size distribution which influences the amount of magnetic particles

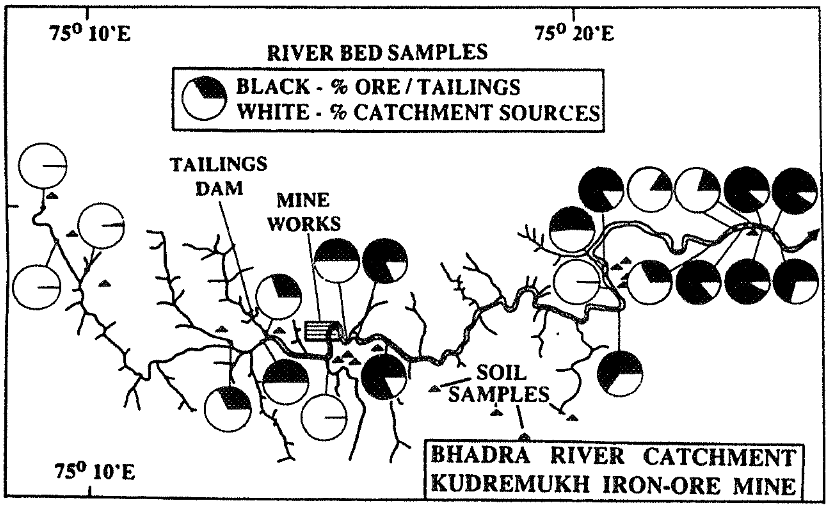

Fig. 1. Proportions of ore + tailing and catchment soils in Bhadra river-bed sediments.

present in river samples. Thus, one can see the fingerprint of particulate pollution in quantitative terms in the Bhadra river. Seasonal sampling and studies along these lines would provide a clearer picture of the amount of particulates entering the Bhadra river drainage system and eventually the Bhadra reservoir. Frequent sampling and magnetic measurements will be easy because rock magnetic techniques are simple, rapid and inexpensive.

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