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Chromium (VI) in Waters in Parts of Sukinda Chromite Valley and Health Hazards, Orissa, India

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All forms of chromium can be toxic at high levels but hexavalent chromium is more toxic than the trivalent or tetravalent. Hexavalent chromium is also more soluble in water than other two forms. Because Cr^{-6} hydrolyses extensively, only neutral or anionic species occur in water (Kumaresan and Riyazuddin, 1999). In biological systems, hexavalent chromium is extensively mobile. Consequently Cr (VI) is of great importance in environmental studies and food contamination, since its excessive concentration is detrimental to health as this could be involved in the pathogenesis of certain diseases such as lung and gastro-intestinal cancer (Baetjer, 1956). In India, the largest chromite deposit occurs in the state of Orissa in Sukinda valley. At present the deposits are being exploited mainly by opencast mining methods. Almost all the mines in this area are manually operated. Thus the area is highly populated, "Bhuban" being the famous village near by, which happens to be the largest (in terms of its population) village in Asia. Water seepage from the mine dumps, which lie on the bank of Damsala Nala that traverses the valley and water from quarries cause the contamination of water by increasing the concentration of chromium in it rendering the water unpotable.

A study of the water in this valley with respect to the concentration of hexavalent chromium has been carried out, which clearly reflects the influence of sources of pollution stated above particularly of mining activities in the valley. The purpose of this study was to assess the pollution as a health hazard.

MATERIALS AND METHODS

The Sukinda ultramafic field covers an area of about 55 sq. km., bounded by latitudes 21^0 01' N and 21^0 05'N and longitudes 85^0 40'E and 85^0 53'E (Fig. 1). The field occurs in the valley zone between two prominent hill ranges, Daitari to the northwest and Mahagiri to the southeast. Damsala Nala, which is a perennial stream flowing westerly through the central part of the valley forms the main drainage system. Almost all small streams and the drain out water from quarries meet ultimately with Damsala Nala. Chromite mines are located at the northern hill slopes of Mahagiri range and in the valley area (Mahalik *et al.*, 1986). The ultramafics of Sukinda valley along with the associated chromite bodies are

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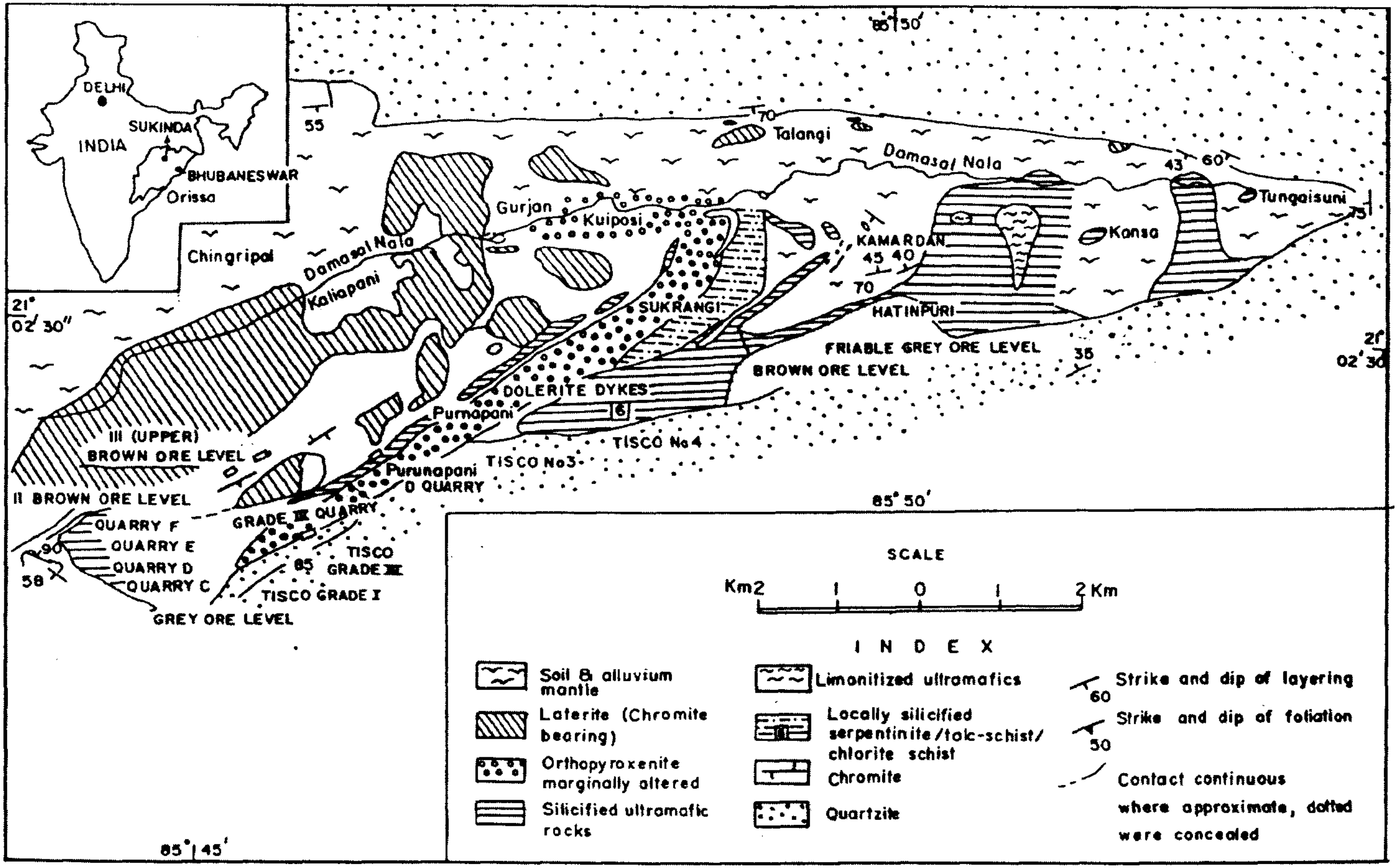

Figure 1. Geological map of Sukinda valley.

intrusive into lower sequence of the Iron Ore group and is cofolded as a south-easterly plunging syncline (Balakrishanan, 1994). The ultramafics, which carry the chromite deposits, have been completely serpentinised. The deposits are generally of friable nature.

In the area, many private as well as Government agencies were engaged in the mining activities e.g. Tata Iron and Steel Company (TISCO), Orissa Mining Corporation (OMC), Ferro Alloys Corporation (FACOR). For the purpose of present study twenty-seven water samples (Table 1) were collected from different effluent channels, washing discharge, colony drainage water channels, quarries and directly from Damsala Nala. Again eighteen drinking water samples (Table 2) were taken from tube wells, dug wells and from different filter house set up by different agencies for treatment of water. The samples are collected from the mine area as well as from township. All samples were collected in high-density polythene bottles and stored at 5^0C. Also, concentrations of Cr(VI) in ten different observational sites (Table 3) for two consecutive years have been collected. Site description for different samples (Fig.2) are as follows:

Table 1. Site description for surface water samples

S1.	Effluent in quarry-D at south Kaliapani
S2.	Effluent in quarry-C at Kaliapani
S3.	Damsala Nala, near quarry-C, Kaliapani
S4.	Near temple, Kaliapani mines
S5.	Kathpal chromite mines, Ferro Alloys Corporation (FACOR), jungle pit
S6.	Kathpal chromite mines, washing discharge
S7.	Kathpal chromite mines, near Damsala Nala
S8.	Quarry water from Kamarda mine
S9.	Effluent in quarry-F at south Kaliapani
S10.	Quarry III at Kaliapani
S11.	Kaliapani discharge before meeting Damsala Nala
S12.	Discharge from quarry-F, Kalrangi
S13.	Open cast quarry discharge to Damsala Nala
S14.	Washing line effluent discharge to Damsala Nala
S15.	Orissa Mining Corporation (OMC) mine drain
S16.	Effluent channel at chromite beneficiation plant of Tata Iron and Steel Company (TISCO).
S17.	TISCO mines and colony drainage water channel
S18.	Damsala Nala at Kansa village
S19.	Damsala Nala near Talangi mines
S20.	Damsala Nala near Saruabil village
S21.	Damsala Nala- on the road to Ostopal, upstream of Kaliapani
S22.	Damsala Nala- on the road to Kathpal
S23.	Damsala Nala- upstream of discharge from Kaliapani mines
S24.	Damsala Nala- downstream of discharge of TISCO mines
S25.	Near TISCO beneficiation plant
S26.	TISCO- overflow water from quarry-X
S27.	TISCO- final effluent to Damsala Nala

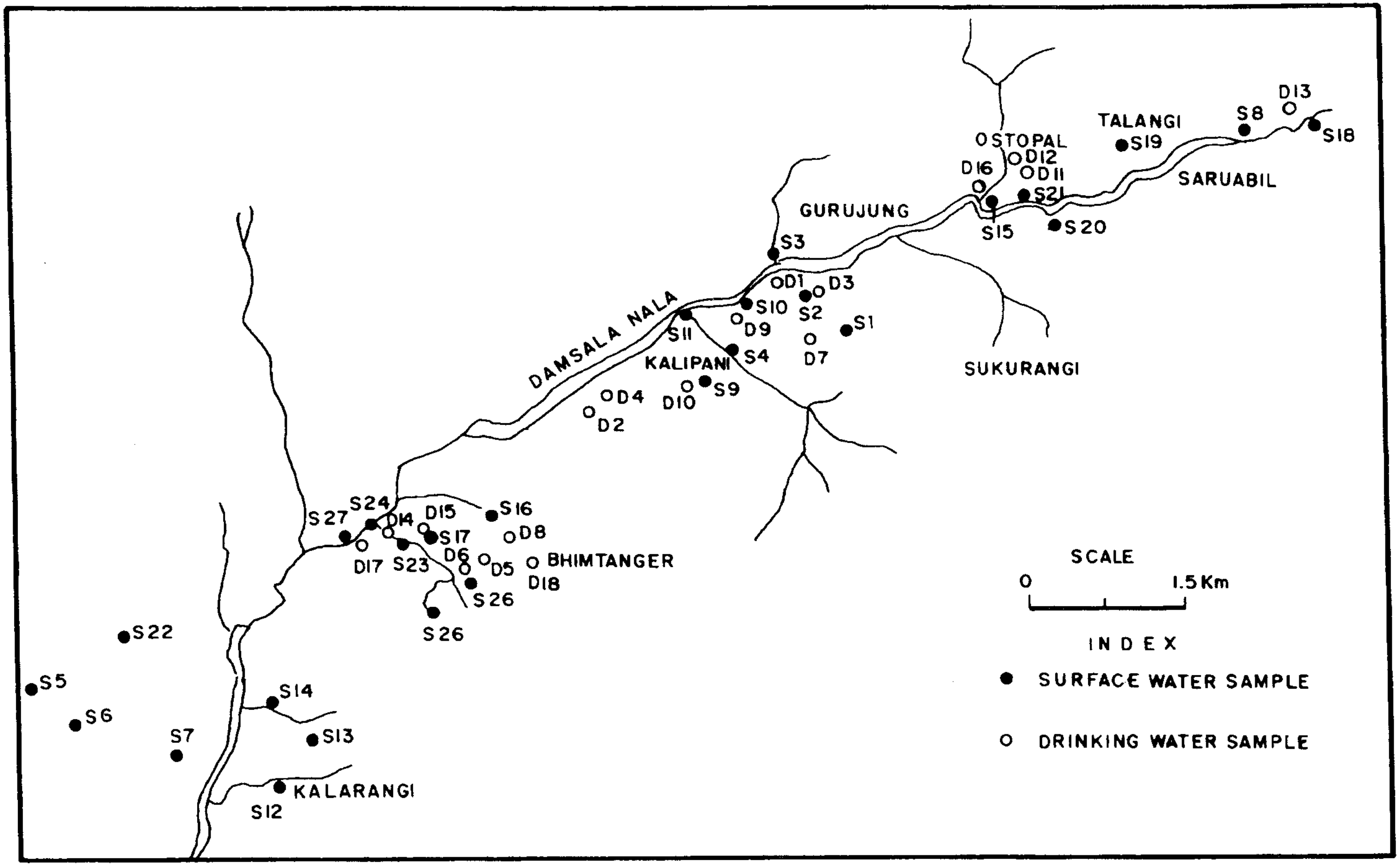

Figure 2. Location map of surface water and ground water samples

Table 2. Site description for drinking water samples

D1.	Tube well water at Kaliapani
D2.	Tube well water at Chirgunia
D3.	Tube well water at Kaliapani Township
D4.	Dug well water at Chirgunia
D5.	Dug well water at TISCO post office
D6.	Canteen water at TISCO
D7.	Water at mining site of quarry-D, south Kaliapani
D8.	Guest house water of TISCO
D9.	Water of hotel at quarry-III, south Kaliapani
D10.	Tube well water near the school on the way to south Kaliapani
D11.	Water at Ostopal mines township
D12.	Water at Ostopal canteen
D13.	Water from Kamarda tube well
D14.	Near filter house of OMC
D15.	Drinking water supplied to house of OMC Township
D16.	Water at Ostopal filter house
D17.	Water from near the TISCO filter house
D19.	Water near the Ostopal township hospital

RESULTS AND DISCUSSION

The concentration of hexavalent chromium in different surface water samples and in different drinking water samples of Sukinda chromite valley have been given in Table 3 and Table 4 respectively. Surface water analysis results (Table 3) show that the mine discharge water in general contains the major pollutant hexavalent chromium above its permissible limit for households (i.e. 0.1 mg/L). It also touches as high as 52 mg/L in effluent channel at chromite beneficiation plant of TISCO (S16) and as low as 0.02 mg/L in Damsala Nala- downstream of discharge of TISCO mines (S24). 70.37% of the surface water samples analyzed possessed Cr(VI) concentration more than the safe level (i.e. 0.1 mg/L). It is evident from Table 4 that, the water supplied for drinking purpose by different agencies and water from tube wells and bore wells also have Cr(VI) concentration more than the permissible limit. 61.11% of the drinking water samples analyzed possessed Cr(VI) concentration higher than the permissible limit. The concentration shows as higher as 0.6 mg/L in water at Ostopal mines township (D11) and as low as 0.0 mg/L in water near the TISCO filter house (D17). The water used in this area for drinking purpose is supplied from tube wells, dug wells and from water treatment plants set up by different agencies.

From the analysis of surface water samples as well as samples collected from water used for drinking purpose in the area, it is evident that, both of them are having Cr(VI) content much more than the permissible limit i.e. 0.1 mg/L.

The contamination of surface water in the mining area is due to 1) discharge of water from mine and workshop, 2) rain water overflowing from dumps, and 3) dumps collapsing by the river side and mixing in water.

Table 3. Concentration of Cr(VI) in surface-water samples

Sample No.	Cr(VI) in mg/L	Sample No.	Cr(VI) in mg/L	Sample No.	Cr(VI) in mg/L
S1	0.35	S10	1.12	S19	0.06
S2	0.16	S11	0.2	S20	0.09
S3	0.06	S12	0.16	S21	1.18
S4	0.25	S13	ND	S22	0.16
S5	ND	S14	0.08	S23	0.08
S6	4.0	S15	8.0	S24	0.02
S7	ND	S16	52	S25	0.96
S8	6.0	S17	5.68	S26	0.08
S9	1.6	S18	0.03	S27	0.60

Table 4. Concentration of Cr(VI) in drinking-water samples (mg/L)

SampleCr(VI) No.	in mg/L	Sample No.	Cr(VI) in mg/L	Sample No.	Cr(VI) in mg/L
D1	0.25	D7	0.48	D13	0.32
D2	0.12	D8	0.1	D14	0.02
D3	0.12	D9	0.22	D15	0.08
D4	0.28	D10	0.3	D16	0.04
D5	0.12	D11	0.6	D17	0.00
D6	0.4	D12	0.08	D18	0.02

Table 5. Concentration of Cr(VI) in Water in mg/L

Site No.	Conc. in 1993	Conc. in 1994
1	0.662	1.77
2	0.977	2.18
3	0.89	2.04
4	1.24	2.22
5	1.38	1.78
6	2.35	3.55
7	2.35	3.82
8	1.82	3.15
9	2.27	3.95
10	2.40	4.98

Table 6. No of cases of gastro - intestinal and skin–irritation.

Year	Gastro-intestinal	Skin-irritation
1987	750	200
1988	700	600
1989	1050	550
1990	1050	600
1991	1100	900
1992	1125	950
1993	1200	1075
1994	1250	1135

Dewatering was being done continuously to enable the mining activity to continue. As a result water from deep open cast mine containing particles of chromium is discharged to the Damsala Nala causing contamination. Rain water while overflowing from over burden dumps, may get mixed with fine rock particles which contain the toxic hexavalent chromium and dissolve it. Again, the Cr(III), which is insoluble in water, by oxidation, converted to Cr(VI) in the presence of natural rain water containing free oxygen and get dissolved in the rain water. Most of the mine dumps lie on the bank of the Damsala Nala. As a result the mine effluents go into the Nala directly. The concentration of Cr(VI) in different location in the area , in two consecutive years 1993 and 1994 have been given in Table 5 and plotted in Fig. 3 which shows the concentration in 1994 is greater than that of 1993.

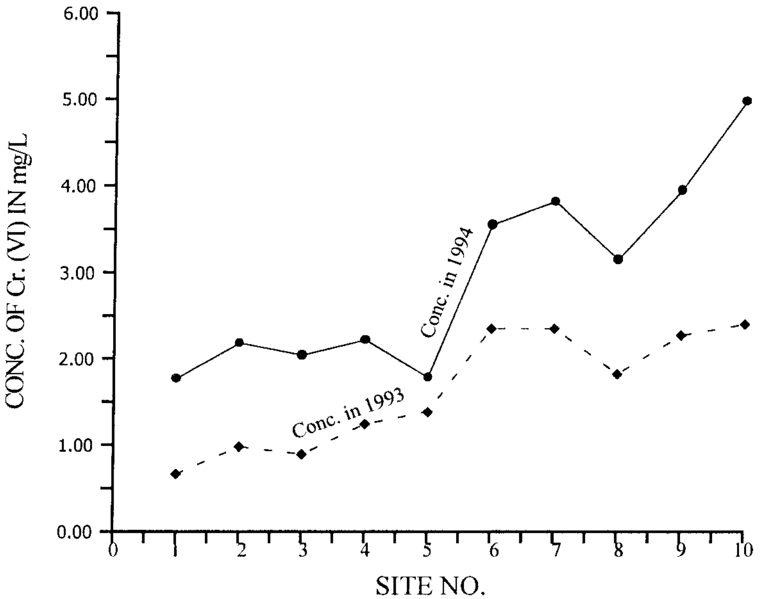

Figure 3. Concentration of Cr(VI) in 1993 and 1994.

The persistence of Cr(VI) in water has serious implications both for human and aquatic fauna due to its toxicity. One might be exposed to chromium by breathing contaminated air, ingesting water or food from soil near waste sites. Oral ingestion of hexavalent chromium compound may lead to intense irritation of gastrointestinal tract and can cause stomach upsets and ulcer, convulsions, kidney and liver damage and even death (Baetjer, 1956; George and Guthrie, 1992). The hexavalent chromium compounds exert an extremely irritative, corrosive and under some circumstances toxic action on the body tissue. The harmful effect may be due to the oxidizing ability of these compounds. Skin contact with liquids or solids containing Cr(VI) may lead to skin ulcers. It has been established that, Cr(VI) is a carcinogen. The number of cases of gastrointestinal and skin-irritation from the year 1987 to1994 have been given in Table 6 and plotted in Fig.4 which shows an increase trend.

The present mining activities and expansion of mining activities in the future are expected to increase the Cr(VI) content in groundwater as well as surface water Nayak, 1995). For supply of safe potable water, more water treatment plants in the area are to be set up. However stringent measures to prevent leaching mainly from stockyards, overburden dumps and abandoned quarries are to be taken care of 1993.

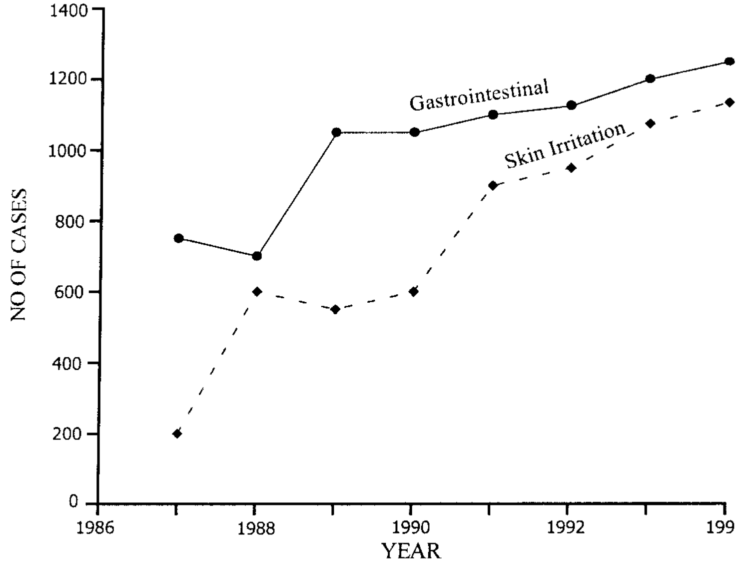

Figure 4. Gastrointestinal and skin irritation cases.

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