TheStrategiesof chromite terrace in Sukinda Valley; India

Abstract

Comment [H1]: Is not possible identifier the purpose of the study , neither the conclusions

Iron chrome oxide ($FeCr_2O_4$), is a commercially viable and major ingredient of stainless steel.The Odisha state in India possesses 98% of the pre-Cambrian India's Chromite ore deposits in Sukinda valley, Jajpur District. To meet the present escalatingdemand it is urged to extract more chrome ore to satiate domestic needs. The depletion of chrome deposits, rise in demand, fewer chrome mines,and less conversion from tailings shall pose problems in the future. Gradual conversion from trivalent to toxic hexavalent chrome ion level in the geo-bio hydrosphereshall create grave health concernsfor the people,fauna, and flora in Sukinda valley.

The present questisa visit to the mines area,the status of chromite mines, ores, and the tailings using the X-ray fluorescent spectrometer.Interactions were made about the sustainabilityofthe people,land, water, and environment of the Sukinda ultramafic complex. Searching the past literature, research results, and electronic/ print media news, staying in the area has helped in the preparation of the compendium. The objective is preparationa strategic plan through Environmental Impact Assessment and Environmental Management Plan using GIS methodologies.

CR (III) is a dietary requirement. The anthropogenic activities and atmospheric exposurehave converted Cr (III) to Cr (VI) in SUC and have surpassed the recommended values.The noxious Cr(VI) shallinvitehealth and environmental distresses in the future.The aboriginals are economicallyburdened, with food security, poor livelihood, health, and in societal values. The Sukinda Valley ore samples contain 50% chromite ore are economic whereas the % of CR (III) ore in the tailings (>7%) of SUC mines is also possible to meet the future demand.The surging mining activities warrant Cr (VI) free geo-bio and hydro environment in the future expected exorbitant Cr (VI) in Sukinda valley.

Keywords: Carcinogenic, EIA/EMP studies, Geology,Chromium mines**,** Sukinda Ultramafic complex**,**Hexavalent.

Introduction:

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Is not identifiable the purpose of the study
It is possible assume that this is a review article but this should be indicated in the title

The Sukinda Ultramafic Complex (SUC) is housed in about 200sqkm in the Sukinda valley of Jajpur district, Odisha, India. The existent open cast mine has the problems of management of the tailings and overburdens, deterring the future exploitation of mining activities. The Odisha Mining Corporation Ltd (OMC), started Sukrangi (1980); Kaliapani (1967), and south Kaliapani (1980); Chingudipal (1997), and Sukinda (1999) of Indian Metals & Ferro Alloys Ltd (IMFA), Kathapal (1973) and Kalarangi of Vedanta (2010) (old FACOR) from (2020), Kaliapani (2002) of Jindal; Kamarada (1967) of B.C Mohanty & Sons; Telangi (2004) of IDCOL; and TISCO at Sukinda from 1960 (Saruabil-Kamarda mines of Tata Steel Mining, Balasore Alloys Ltd, Balgopalpur,Jajpur,Ostapal of Vedanta,Sukinda and Mahagiri mines of IMFA and Misrilal Mines (P) Ltd, Jajpur are the other major mines complexes.

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The Sukinda Valley (Topo sheet no F4516(73G/16), lies between Mahagiri Hill (707.69m in the South) and Tomka Range (782.42m in the North).The mining activities are both open-cast and underground (UG) (**Fig 1-B**). There are four defunct and closed mines in the SUC valley like FACOR, OMC (Kalangaraji, and Katha pal), and IDCOL (Tailangi chromite mine) debarring the livelihood of about 4500 dependent mining workers.

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Global Chrome alloy manufacture (Ferro and Charge Chrome) has been projected at 11.0 MTPA where India shares ≈ 0.9 MTPA (8%) due to growth in Carbon steel (1380 MTPA), Stainless Steel (31 MTPA), and Alloy Steel (20 MTPA). About 4.25MTPA (36%) of the global Chrome Alloys consumed inChina and the country is imported at a large scale. In the future, India shall encounter a shortage of Chrome and shall be forced to export. Chrome mining in Odisha commenced in 1953, still, India shall be unable to meet the market after a decade or so. The geo-bio-hydro sphere in and out of the mines in Jajpur,Odisha is on the borderline and not away from acute chromium toxicity and hazard.

Sukinda ultramafic complex (SUC) hasoptimum numbers ofopen cast fully mechanized mines and underground mines (UG) in Asia. TISCO is the first mine thatbaggeda lease to its Ferrochrome plant in 1953and operation TheOdisha mining corporations limited (OMC) a government of Odisha undertaking has been engaged in chrome mining. It is the first beneficiation plant in India to bag ISO 9001 to quality management systemsfrom 1993 (Fig 1)

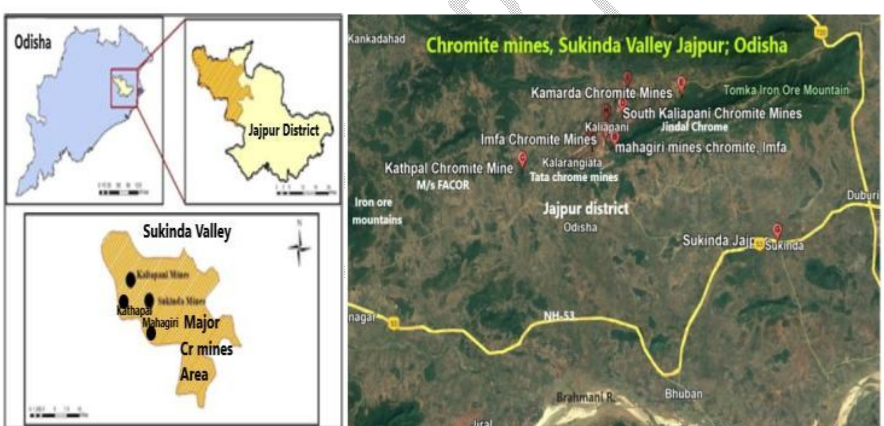

Fig 1(left (L) & right (R)): The index map of Sukinda chromite mines areas, in Sukinda valley

Study area

Comment [H5]: Usually, this description is in methodology but if it is a review article is correct here

The Sukinda ultramafic complex (SUC) of the Precambrian age(200 53'-210 5'N and 850 41'- 850 53'E) is located in the Jajpur-Dhenkanal districts of Odisha with a present population of about 80000 including mining workers. Thechrome mines aresouth of the Northern part of Iron Ore Craton (NOIOC) and dash the marginof the EGSG (Eastern Ghats Super Group).The various open mines in the SUC are OMC (Kaliapani, South Kaliapani, and Sukrangi) (**Fig 2**L)F, BC Mohanty chrome mines (Kamarada, defunct), FACOR at Ostapal (defunct), IDCOL at

Tailangi (defunct), IMFA (Chingudi- pal and Sukinda), Balasore alloys (Kaliapani defunct), Jindal (South Kaliapani),Saruabali of ML minesand TISCO (Sukinda), and the only Under Ground mines existing at FACOR (Kathpal; defunct).

Fig 2(L & R): Chromite mine at Kaliapani (S), with the Damsala nallah Sukinda,Jajpur, Odisha

Chromium requirement:

Comment [H6]: This is part of review? If it is the situation, should be clearer the subtitle. Chromium requirement in ……… industry, health or others?

Chromite ore and ferrochrome are expected to remain strong as stainless steelproduction in India has surged to 5.4 million tons in 2020. The ferrochrome ultramafic belt of the SUC, and extendsto the east ofthe Kansa area. The Ferrochrome plant at Jajpur Road exists very close to the mining areas. The chrome ore (96% of total extraction) is used in the manufacturing of ferrochrome as it comprises carbon Ferro carbon (steel) ≈94 %, ferrochrome (≈4%), and 2% MC ferrochrome). The balance chrome ore (4%) has its application in the foundry, chemical, and refractory industries (OSPCB, Odisha 2008[1], M/s Jindal steel Pvt EIA/EMP study, 2018[2]).

In the early 19^{th} century, chrome was used in the manufacturing of paints, and tanning salts. But later used for making alloys with iron, nickel, and tungstento produce superalloys(making tools, rusting and coloring of pipes,armor-plating,and forjet engines). About ≈85% of Chromiumis used in the industrialization of stainless steel (strong and rust-resistant).It is also used in making industrially used processes likethe tanning of leather, and in the textile industries to impart yellow colour.The demand for chromite is mounting around the globe and so also in India. Presently India is fulfilling its demand from indigenous sources but in the future, India shall expert chrome/ ferrochrome to meet its internal demand.

Review of Literature:

Comment [H7]: What is this??

Sukinda Valley is an iron ore and chromite mines area, highly polluted generating tons of mining tailings and overburdened waste, causing serious health and environmental issues.Hexavalent chromium poses healthcare issues in the area. Little research results are available to address the increasing pollution, (Nayak et al., 2020[3]).Occupational hazards related to Indian chromite mining industry areas are a lot along with occupational Safety and Health Administration (Das et al., 2011[4]). The oxidation of chromite Cr(VI) mineral present in tailings and overburden in Sukinda, India, has been found associated with the poisonous Hexavalent chromium (Dhal et al, 2013[5]). The groundwater in and around the chromite mines has been polluted due to mining seepage /leachate migration as the habitats in the vicinity are fronting groundwater complications (Dhakate et al., 2008[6]). Tenacity in the geo-bio-hydrosphere, the chromium metal is greatly poisonousand deadly to all living bodies due to intercellular accumulation and is widely accepted as environmental noxious waste.The chromite mine workers, stakeholders, land users, and steel welders are prone to the toxicity of Cr (VI) contamination as per OSHA and WHO, (Sharma et al, 2022[7]).

In the water resources that are present in and around the SUC, people are suffering from kidney problems, poor oral health, and carry Gas intestinal disorders, carcinogenic of the bladder, larynx, lungs, bone, thyroid, etc., Deng et al., 2019[8], Tumolo et al, 2020[9], Pineiro et. al,2021[10], Kumar et al, 2022[11].The Central Pollution Control Board (CPCB) and WHO stipulations, the conc. level of hexavalent chromium in portablewatershould not be higher than 0.05 (mg/l). The conc. level of theCr (VI) ion in the Sukinda valley is > 2.5 mg/l and it is noxious for the health of stakeholders and animals, (Dubey et al., 2001[12], Kumari et al.,2017[13]).

The reuse and valorization of the ferrochrome or chrome tailings have proved to replace about 50% of fine aggregates in cement concrete, in making bricks, filling pits, and also in road construction like ground granulated blast furnace slags, (GGBS) and red mud (Nayak et al., 2020[3], Mallick et al, 2020[14], Das M et al., 2020[15], Harichandan et al., 2022[16])

There is about 17% transformation of tri to hexavalent chromium in sludge under aerobic conditions within a month but alarmed the 30 days, the conversion by oxidation escalates due to rain, accumulation of effluents, runoffseepage, and percolation under field settings of dispersal of Cr(VI) pollutionApte et al., 2006[17].Natural conversion of Cr(VI) to Cr (III) in chrome mines area can be done by Live Spirulina platensis on Bio-sorption, adsorptions, ion exchange, or filtration methods.Cr (VI) is available as $HCrO^{4-}$and chromate at pH > 6.5 but in Groundwater, it is a byproduct of many industrial processes Regan et al, 2019[18].

Study objectives:

Comment [H8]: This is confused. Normally the objective (only one) is present in the last paragraph of the introduction not as part of review of literature

With the growth ofthe use of steel and ferrochrome, the demand for chromium has surged. India is one among other countries that export Chromium to China and Japan.Hexavalent chrome serves as a polluting intoxicant to human health. With increasing anthropogenic activities it is entering the environment through the geo-bio-hydrosphere. The present research aims toinvestigate the geological formation of the area, and to know about the degradationof the geo-

-bio-hydro atmosphere.Particularly it is about the water resources sector, effluent water disposal. To meet the demand for chrome ore in the future, an urge to import chrome ore from other countries is foreseen. The depletion of ore deposits, effluent disposal, OB, and tailings management shall create grave concern in India. Ten of the Chrome mines have ETP whose input and output effluent analysis is done.

Methods and Methodology:

Comment [H9]: ??? What type of article is this manuscript?
If this is a original article the introduction is not clear, is excessive and confused

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The SUC in Sukinda Valley has the problems of disposal of overburdens, deterioration of forest against anthropogenic activities like deforestation, settlement for surging population, and development of plants and industries, etc. The present study is effective for controlling mining wastes, projection of chromite reserves, pre-feasibility studies, environmental impact assessment (EIA), future invasive processes, etc. ARC GIS is one of the best tools to prepare the digital elevation model. The Slope deviceof GIS software can be operated to generate a slope map by recognizing the slopefrom each cell of the raster surface.

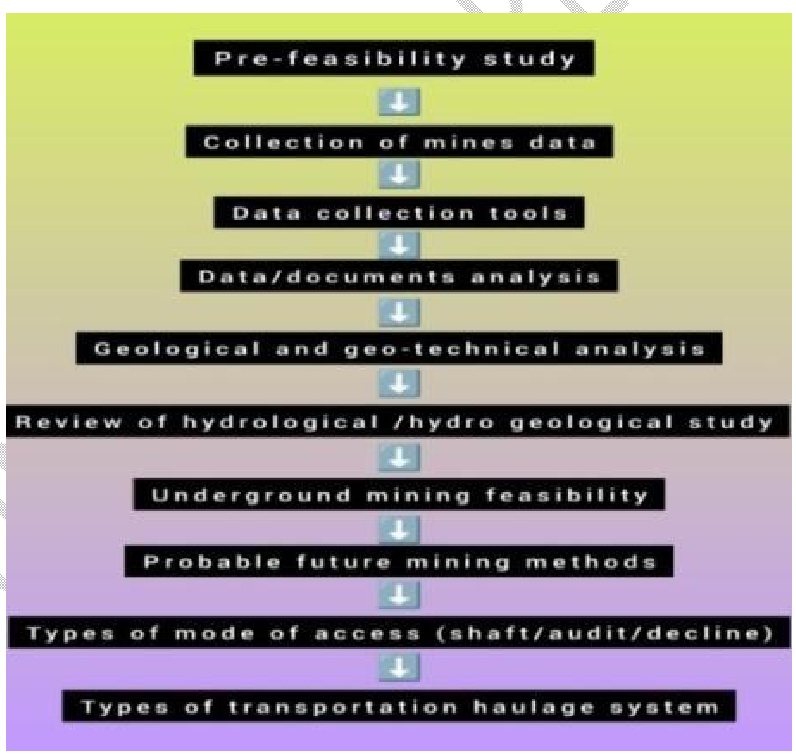

Fig 3: The methodology of the Present Sukinda Chromite mines

A slope map generation is not generated directly from contours as the Slope tool is incapable to support the vector data. The Slope tool is used for creating the slope map of an area by isolating the cell slope from a raster surface. Contour lines are the line features in the shapefile or the vector data from the feature class. Slope data does not support vector data. Using this DEM the drainage, Aspect, and LULC map of the area can be prepared.

History of Chromite:

Johann Gottlob Lehmann, misidentified lead chromite in the Ural Mountains (orange-red mineral) named wrongly as Siberian red lead, in 1761.Vauquelin N.L. (1797), produced chromium oxide by mixing crocoite with hydrochloric acid in the laboratory. Later In 1798, Vauquelin isolated metallic chromium by heating the oxide in a charcoal oven. He detected traces of chromium in precious gemstones, like ruby and emerald. In 1800, Tassaert of German during his research in Paris detected chromium as an ore and called it chromite.

Chemistry of chromium

Chromium, a pentavalent element available in nature (frustum of earth and underneath sea) exists in the form of various oxides (-2 to +6) out of which the trivalent and hexavalent elements are the most stable. Industrial effluentsand wastewater from pits, OB, or tailings are the fonts of Cr (VI) pollutants in the environment. CR (VI) contamination is one the serious environmental and health distresses due to its long persistent exposure, ((Tchounwou et al., 2012[19],Daneshvar et al, 2022, [20]). Cr (III) is existing in nature normally as Ferro-chromite ($FeCr_2O4$), and Cr (VI) is mostly generated by oxidation or chlorination from anthropogenic activities and is highly toxic to living organisms (Sharma et al., 2022[7]). Chrome tailings are collected from Old TISCO mines at Sukinda and the chemistry is tested by XRF (Omnian XRF), CUTM. The extracted ore sample has 50% of chromite (Fig 4)& (Table- 1).

Chrome ore Sample I

Compound	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3
Conc	10.266	13.247	0.294	0.165	834.5	0.232	1.059	0.309	750.9	51.327	0.818	21.774
Unit	%	%	%	%	ppm	%	%	%	ppm	%	%	%

Compound	NiO	CuO	ZnO	Ga_2O_3	SeO_2	Rb_2O	SrO	SnO_2	IrO_2	CO_2	Re
Conc	0.251	76.6	505.6	0.0	43.5	18.3	64.6	162.1	117.9	0.0	8.1
Unit	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm

Chrome ore Sample II

Normalisation factor : 1.589

Compound	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3	NiO
Conc	10.592	12.955	0.326	0.107	0.108	0.255	1.222	0.293	946.6	50.031	0.825	22.821	0.275
Unit	%	%	%	%	%	%	%	%	ppm	%	%	%	%

Compound	ZnO	SeO_2	Rb_2O	SnO_2	IrO_2	CO_2	Re
Conc	548.5	55.0	19.2	173.9	152.7	0.0	13.6
Unit	ppm	ppm	ppm	ppm	ppm	ppm	ppm

Fig 4: Chrome ore samples from Sukinda Ultramafic complex studied under Omnian XRF,

Similarly, the tailings from ore sites are collected, and found that the % of chromite ore present in the samples lies between 7-8% which is an appreciable amount.

Table 1:The chemical ingredients of the Tailing samples collected from the Sukinda valley

Chrome	Ratio	Cr_2O3	MgO	FeO	Fe_2 O_3	SiO_2	Al_2O_3	S	P	LOI
Samp-1	%	7.68	33.20	2.45	4.77	35.91	3.53	0.1	0.01	17.57
Samp-2	%	7.64	28.25	2.64	4.33	25.61	4.23	0.1	0.01	27.38
Samp-3	%	7.72	30.26	2.53	4.68	31.64	3.06	0.1	0.01	24.44

The Sukinda Valley ore samples contain 50% chromite ore are economic whereas the % of CR (III) ore in the tailings (>7%) of SUC mines is also possible to meet the future demand.

Effect of Cr (VI) on human health:

On human and faunal **impact**: Chromium VI contamination in the atmosphere has toxicological effects on the respiratory, mutagenic, genotoxic, cardiovascular, and reproductive systems of humans, (Liang et al, 2021[21],Hossiniet al, 2022, [22].The lower concentrations (Conc.) of Cr (VI) stimulate alveolar lung phagocytic activity and the immunological reaction. The Cr (VI) ata higher concentration inwater and air depresses the macrophage phagocytic activity and the immunological responses and make the death of cells in the body, (Mishra S. et al., 2016 [23]). Chromium (Cr) causes Kidney dysfunction, DNA damage, GI disorders, Genomic instability, dermal diseases, Oxidative stress, and ROS generation. It is observed at high levels of contamination, Cr (VI) increases the frequency of cancers and ulcerations inthe thyroid, larynx,lungs, kidneys, testicular, bladder,and bone, (Deng et al., 2019[24]; Pavesiet al., 2020[25], Balali-Mood et al., 2021[26]).

On Faunal and micro-organisms

As biological, the Cr (VI) effect in plant metabolism has deferrals on germination, damages roots, delays roots growth, lowers the yield, abridge biomass, dwarfing of plants, leaf chlorosis, photreduced biomass, reduced plant height, photosynthetic impairment, membrane damage, leaf chlorosis, necrosis, low yield, and ultimate death of the plants, Photosynthetic impairment, membrane damage, necrosis,and ultimate death of the plant, (Prasad et al., 2022[27],Sharma et al., 2022[7]).

Effect on land:

The overburden, and tailings in the chrome mines, from the metallurgical activities, refractories, and chemicalindustries chrome ions are released and pass into the soil nearby. Also in the chrome ore terraces, specks of dust, water ponding, and seepage to the groundwater table raise the chrome ions in the geo-bio and hydrosphere. The tri and Hexa valent chromium ions are highly noxious and mobile. They enter the food chain through bioaccumulation, affect the flora and faunal domain and affect the faunal metabolism, productivity, reproduction, and even marine life, (Shankar et al., 2005[28], Sharma et al., 2020[07],Saud et al., 2022[29])

Effect on atmosphere:

The stable ions of tri and hexavalent chromium are poisonous and join the air, and soil has negatively upsets the humanrespiratory, cardiovascular, and reproductive systems. It affects plant metabolism and hinders crop growth, harvest, and grain quality. TheCr(VI) exposure and contact can cause asthma, irritation or damage of an eye/nose/skin, perforate eardrum, respiratory tractirritation, damage of thekidney, and liver, congestion, and edemaof the pulmonary system, abdominal pain, respiratory tract malignancy. Thus, the level of Cr (VI) needs to be monitored in the SUC valley regularly and analyzed from time to time and recursive occurrences to be attended to through preparation action plan must be prepared and implemented, (Zayed et al., 2003[30], Sharma et al., 2022[7]).

Chrome ore deposits in India:

The chromite consists of 68% chromium (Cr_2O_3) and32% iron oxide (FeO). The countriesthat explored chrome ore in the year 2021 were South Africa (18000ThMT), Turkey & Kazakhstan(7000^{Th}MT), India 3000(ThMT), and the world (rest) (6400^{Th}MT). They have four grades, likeMetallurgy -I (More chromium chromite, least $Cr_2O_3$40%), Chemical(more iron chromite, least 46% Cr2O3), Foundry-3 (low silica chromite, more 45% Cr2O3), Refractory (more aluminum chromite, 46% Cr2O3); www.fastmarkets.com/industrial-minerals/chrome-and-chromite.

Chromium deposit in Odisha: The chromium deposits are available in Jajpur, Keonjhar, Dhenkanal, Balasore, and Cuttack districts of Odisha, and themaximum 98% of them are in Sukinda Chrome Valley (SUC).Out of the total availability of chromite ore about 97% of them is deposited in the westerly sloping valley between (latitudes21◦00′00″ to 21◦03′′00″ N and longitudes 85◦44′00″ to 85◦48′00″ E) and(20□53'-21□05'N & 85□41'-85□53'E).

Climate: Wind speed is calculated to be 2.3m/s. 24.33% of the time the wind is calm. The main wind direction is observed to be from the west direction. The average monthly rainfall is recorded to be 10.6mm. The major atmospheric geo-bio-hydro degradation along the valley with pollution is the impact of climate change.

The anastomosed drains:

The chrome mines in India are given in **Fig 5(L).** The chromite area in SUC is covered by laterites and frustum by latosol (Moorum) or alluviumof highly weathered materials (soil) inthe open pit. The waste dump on the north side of some of the mines acts as a barrierto determine the flow of the natural slope.No perennial rivers is passing through the SUC but seasonal streamlets / drains present in Damsala Nala -1.5 km (N) (Fig 2 R), Damsel Canal - 4.5 km (SW), Nadibarana Nala -5.0 km (W), Puagaghua Nala-5.3 km (WNW), Ragda Reservior-5.7 km (NW), Sasubhuashuni Nala-6.1 km (NW), Patharkanchia Nala-8.3 km (ESE), Near Natisahi village Canal-9.7 km (ESE), Petapeti Nala-9.8 km (W) considering Kalapani village as the reference point. The overall drainage pattern of the area is dendritic (Fig 6).

As regards the physico-chemical quality of the pit water at Kaliapani (pit water),Giringamali is high above drinking water standards measured by Bhagavati Ana Labs, IMFA both surface and groundwater in 2015 were pH- 8.19 and 8.14 (at Giringamali), Dissolved solid (DS) 220mg/l and 268mg/l (Kampulai), Total solid (TS) 165mg/l and 160mg/l (Kampulai), Cr (VI) ion <0.01mg/l and 0.04mg/l at Gurujang, Fluoride ion 0.30mg/l, and 0.20mg/l at Kalapani, and Kampulai), and alkalinity 135mg/l and 110mg/l (Kampulai).

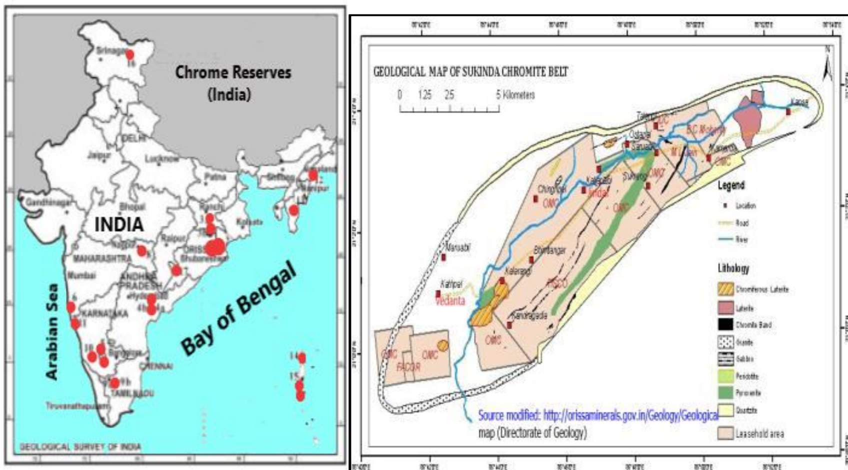

Fig 5: Chrome reserves in India and Chromite mines with leaseholders in SUC, Jajpur district
(Source modified: Geological Survey and Directorate of Geology)

However, it is reported that theKalanangi Bridge near Ostia VillageDamsel river (**Fig 6**)is 0.42mg/l, and the water of Ragada reservoir at Kaliapani was 0.38mg/l which is above the threshold value, (Singh et al., 2011[31], Naz et al., 2016[32], M/s TISCO statement 2019[33]).

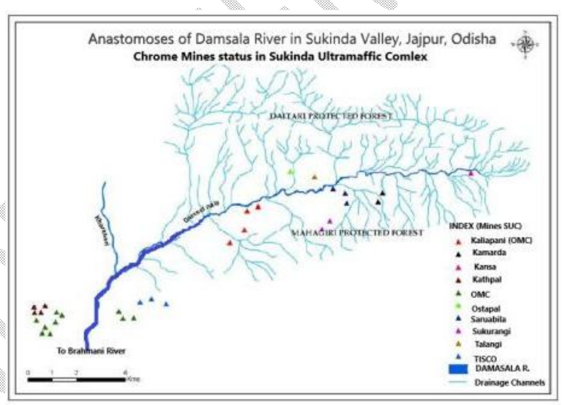

Fig 6: The drainage system of Damsala R. with the chromite mines in SUC.
(source modified: EPG: Orissa)

Chrome ions in surface and groundwater (GW): Literature reveals the accumulation of heavy metals in the high level of concentrations in order Fe > Cr > Mn > Ni > Zn > Pb > Sr in SUC. They exceed the threshold values of eco-toxicological limits in soil**.**The untreated water and the effluents from the designated pits are released into drainsand finally to the perennial rivulet the DamsalaNallah of length about 25km, a tributary of the Brahmani River. The water possesses total Cr (VI) ion concentration (Conc) before treatment was 0.02 to 0.13 mg/L but the annual average value was 0.03 to 0.45mg/l (above thresh hold value) against the permissible value of 0.1mg/l. The Conc. of Cr(VI) of the groundwater in open wells and tube wells ranges from 0.02 to 0.23 mg/L. The surface water of the Damsala Nala and 0.0 to 0.13 mg/L, but exceeds the permissible limits for many days in a year, (Dhakate et al., 2008[6]).TheCr(VI) is positively correlated with sulfate (0.854) in surface water, hardness (0.379) and pH (0.361) in groundwater, and total Cr (0.970). The mine water has a pH (of 6.1 -7.6), and low to moderate total dissolved solids (TDS) (50 -507 mg/l). High total suspended solid (TSS) (4 -64 mg/l) indicates the influence of mine's waste and tailings on the GW quality (Dutta et all 2013[34], Naz et al., 2016[35], Nayak et al. 2020[36]). To date, the values of the surface and groundwater have not deteriorated above the drinking standards except for Cr (VI) ions at the Gurujang, Kampulai, and Kaliapani areas but not at an alarming rate (EPG, Orissa, 2013[37]).

Geological chrome formation:

The stratigraphic chronological order in SUC valley is given as soil & alluvium, Laterite, Pyroxenite, Yellow limonite with Goethite, Limonite with chromite disseminations, Cherty limonite, and Quartzite from bottom to top. The chrome formations are found in three bands, they are Band I: Northern friable chrome ore band, Band II: Middle friable chrome ore band,and Band VI: Southern Lumpy Band (M/s Jindal steel EIA report-2018[2]). The ultramafic rocks accompanying the chromite lodes are in alteration and weathering covered by a thick upper mantle layer of alluvial soil and laterite. The extension depth isabout 300mto 500m with younger pyroxenelayers. They are confined in the Sukinda valleybetween layers of quartzite ridges of Mahagiri (south) to Daitari (south).

Structure and texture:Structure: The Sukinda ultramafic complex (SUC) is housed in theiron ore belt of the Daitari–Tomka mines and the quartzite belts of the Mahagiri areaextending in the north-south direction respectively that befalls in bands, lenses & pockets at the central part of the valley (**Table 2**).

Table 2: Sequence and the Zircon ages of the chromite ore in Sukinda Ultramafic Complex

Geological formation	**Group/type**	**Generalized sequence**	**Zircon ages**
	Kolhan group	KG(time equivalent to Singhbhum mobile belt)	
---------Unconformity---------			
	Dolerite dyke swarms	NDS	
Singhbhum mobile belt(SMB)	Dhanjori-Simlipal-Dalma-Jagannathpur-Mlungtoli and singhbhum group; igneous and sedimentary sequence	Late archean to proterozoic mobile belts(SMB)	
---------Unconformity---------			

	Mayurbhanj granite	SGB-B	3.1Ga
	Singhbhum granite type ii	SBG-B	
Archean granite-greenstone terrain(AGGT)	Iron ore group Igneous and sedimentary sequence. IOG. igneous suite (ultramafic plutonic suite e.g. Nuasahi-sukinda-jojoharu(NSJ): ultramafic suite: Nuasahi-Nilgiri- Gorumahisani-Badampahar (NNGB) grabben-anorthosite- diorite- mafic suite; Ultramafic - mafic suite e.g. komatiiteand high Mg basalts in Goru-mahisani- Badampahar, Tomka- Daitari and Jamda-Koira belts; Felsic volcanic);IOG sedimentary sequences	Iron ore group (IOG)	3506.8 ±2.3 Ma9 age of zircon from deltaic lava within the iron ore group: Tomka-Daitari basin
Older metamorphic group(OMG)-IOG			3121± 3 Ma4 age of zircon from gabbroic suite. Nuasahi breccia zone.
Older metamorphic tonalite gneiss, Singbhum granite, Nilgiri granite, Mayurbhanj granite			3285±7 Ma8 age of zircon from the pegmatitic biotite granodiorite overlain by IOG conglomerate
	Singhbhum Granite Type A	SBG-A	3328 ±7 Ma1
	Older Metamorphic Tonalite Gneiss	OMTG	Age clustering at 3.4 and 3.2 Ga1
	Older Metamorphic Group	OMG	Age clustering at 3.55, 3.4 & 3.2 Ga1

In the northern fringe, amidstthe iron ore group, the chromium ore mass is less prominently demarcated by fault zone depositions in SUC. Chromite bands are offset by dykes, faults & shear zones, which are reflected in their structure. There are two phases of ultramafic. The latest one is composed of Dunite& Peridotite, in later converted to serpentine &limonite.The later phase of the ultramafic comprisesmainly ortho-pyroxenite (enstatite) that is running in NE -SW direction forming the continuous low ridge hence the valley. The layers of chromite are co-folded with the iron-ore super-group into a dipping syncline of formation of massive, banded & spotted, laminated & friable.

The Micro-texture

Textural studies of the chromite in the SUC designate formation by magmatic accumulative differentiation within the ultramafic pile. The grains exhibit cumulus and compact mosaic texture, pull at a distance texture chain or net & orbicular. The pull-apart texture is the distinctive feature of the massive chromite that the chromite grains are stretched to fracturing and further fractured parts pull apart from each other. The ore face near the fault zone is affected by shearing & later deformation that exhibit where the chromite grains brecciated and mylonitizedto very fine fragments of highly irregular shape. The broadening and elongation of the grains may be due to shearing or volume expansion during serpentinization. It can be ascertained that the chromite in SUC is predominantly strati-formand presumably formed insitu by crystal settling.

Tailings/OB in Chromite mines

Outcrop of chromite ore in either powdery or friable form is underlain at a depth of 3 to 10m soft latosol or alluvial overburden, excavated, scrapped, and carried mainly to chrome steel or ferrochrome industries.Tailings on weathering convert Cr (III) to Cr (VI) in the SUZ, which can be reduced using bio-remediation technology in the dead and active mines area that is polluted, and the chrome VI in the air induces cancer of the lungs,(Bolaños-Benítez et al., 2018[38],Ministry of mines-2021[39]).

The overburden (OB) and the tailings should maintain a stripping ratio that varies from 1:5 to 1:10. Failing to maintain the ratio shall pollute the rainwater to generate runoff (make gulley erosion) and accumulate the pits, depressions, and drainage channels and conversion to Cr (VI) by siltation and leaching (EPG Orissa, 2013[37]).

Atmospheric strategies:

Deforestation in mining area: The valley is less yielding, barren hill terrain with sparse vegetation and open scrubs.As mining activities increased, the green belt of Sukinda valley has deformed into a bald terrain.The land is gradually becoming dry, the soil is gradually chromium contaminated warranting immediate local plantation.

Availability of chrome ions in the atmosphere

The major use of chrome in day-to-day activities, industries, and availability in an atmosphere is the making of ferrochrome or steel as it is corrosion free and hard and wear and tear-resistant. Some other practical uses are paints, dyes, polymers, and inks, containing chromate pigments while smelting ferrochrome ores.Plying vehicles, mining activities, stacking, loading, and unloading generate dust and increasethe level of Cr(VI) particles in the atmosphere.

Physiography & drainage pattern: Sukinda is a town in the Jajpur district, of Odisha India. Odisha reserves≈98% of the total ascertained chromite assets of India, out of which ≈97% come about in the Sukinda valley. National Highway 200 passes through Sukinda to transport the mines' materials. In the middle of the valley flows Damsala, a tributary of the river Brahmani at a point far away from the valley. Sukinda chromite belt has a northeast-southwest strike and forms a valley of a V-shape occupying between the Daitari hills rangetowardsthe north and the Mahagiri hill range in the south. Chromite ore occurs in the strati-form type of deposits within the SUCThe mines are located in the Chingudipal, Kalaringatta, and Kansa areas. It extends about 20km in length, from Kansa in the northwest up to Kathapal in the SWdirection of width about 2-5 km with isolated mountains and ridges (Fig 7 and Fig 8).

Fig 7: Defunct, drainage, extraction, and mining of chrome ore in Kaliapani in SUC

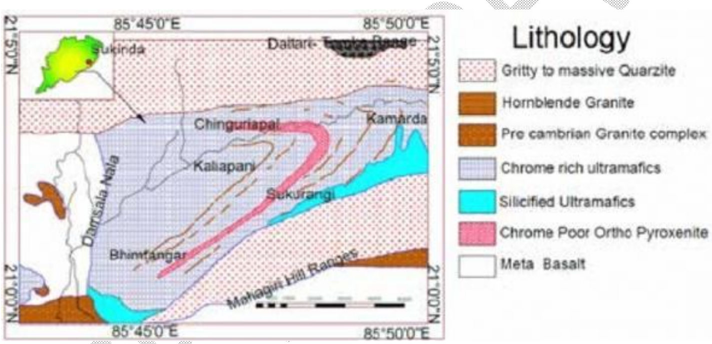

Fig 8: The lithology map of the Kaliapani area in Sukinda valley

The GIS Studies of the SUC area:The steps involved in approaching the GIS maps are:

a. **Drainage map:** this represents the drainage anastomosis of the area under construction. The map is generated from DEM (satellite) or aerial images. It also tells about the drainage pattern of the basin and helps to calculate the drainage density, stream order, and drainage concentration of the area under consideration.
b. **Stream order map:** This map can be generated by using hydrology tools present in the arc toolbox. It is a systematic arrangement that links a stream network by assigning a numeric order. This tells about the girth dimension of that particular stream.
c. **Aspect map**: the aspect map of an area has physical applications such as finding the slope of an area and slope face direction. That indicates the topography, the slope of the vegetation, snowpack of an area. The use of the aspect map can predict the wind direction and exposure of the area.

d. **Hill Shade map:** It is a greyscale 3-D representation of the surface where the sun's relative position is considered for shading of the image.Constructing a hill shade map is to determine the sun’s position by using the altitude of the area and the azimuthal properties of the place under consideration.

e. **LU LC map:** It is usually used for the Categorisation and classification of natural resources along with anthropogenic conversion to nature in a specific frame. The primary use of the land use and land cover map for planning, management, and monitoring of the human settlements, urban agglomeration, and planning of the future topography of the area. The classification of the vegetation is done by using a normalized differential vegetation index (NDVI). Also, the vegetation of the area can protect the soil erosion using USLE or RUSSEL methods of the area.

⇨ $NDVI\ = \frac{\mathrm{NIR-Red}}{\mathrm{NIR+\ Red}}$Where NIR is the near-infrared region of the E.M.S and RED is the longest wavelength of the visible spectrum.

The procedure generates the DEM model (digital elevation model) from the contour line source.

From Raster to vector map: Initially; from the system, toolboxes go to Spatial Analyst tools. Then chose Interpolation and later change Topo to Raster (conversion of topo in the coordinate system and raster in PIXEL form. Afterward, the feature map is prepared from the selected contour as the featureis taken asinput. Then the position is specified from the yielded surface raster. The contour layers range is set which is the output extent. Thus from the contour, the raster layer is obtained.

Preparation of slope map from DEM:

The Digital elevation model (DEM) map has been prepared as perEnvironmental Systems Research Institute, Inc. (ESRI) processes. Usually,the DEM exhibits the elevated features from the datum excluding the earth’s surface features such as vegetation, settlements, or any anthropogenic activities. The procedure involves chronological applications of the system Toolboxes, Spatial Analyst Tools, Surface, > Slope respectively. Repeat the output from Topo to the Raster tool which is considered as the raster input. After designating an output location, it is selected for the output measurement to obtain a slope map from DEM, (Fig 9 (a, b, C, and d)).

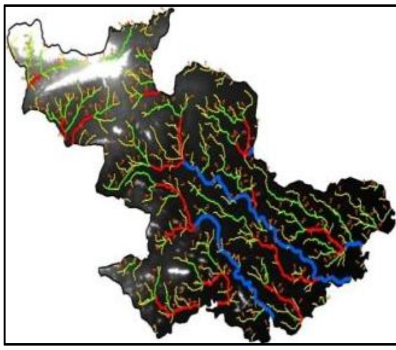 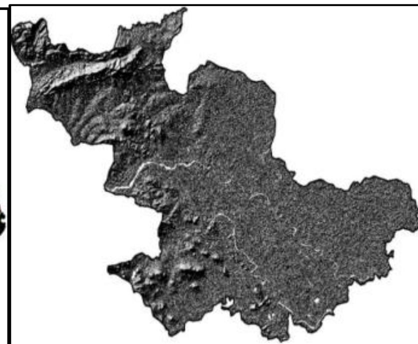

Fig 9(a): The stream order map Fig 9(b) Hill shed map of the Jajpur district

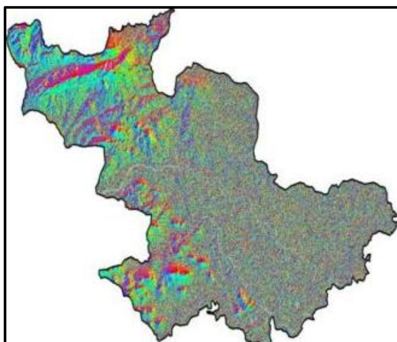 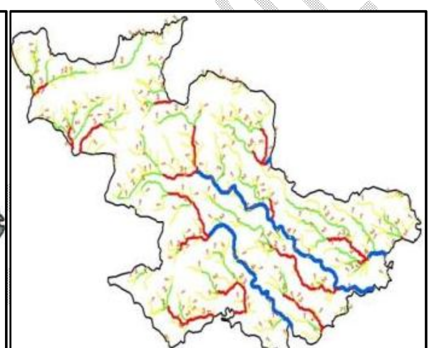

Fig 9(c): Aspect map of the Jajpur area Fig 9(d): The hydrology map of Jajpur (SUC)

From the stream order map, it is ascertained that the area is having streams of order three i.e. the drainage pattern is not that wider and the mainstream is the Dumsala nallah which collects all the discharges and finally falls intothe Brahmani river.There are no large water bodies or settlements within this area, and the groundwater is less influenced by the surface water. The Hill shades of the district show that the western part of the district is full of hillocks, valleys, ridges, and plateaus containing PWM (Plateau weathered moderate), and PWS's (Plateau weathered shallows), Pediments, and Pedi plains.The topography of the hill shades indicates the area is a mining area.The ortho-magmatic formation of the belt is exposed in the form of an asymmetric synclinal valley plunging towards the west–southwest.

The status of Chrome mines in SUC

Various chromites mines presently functional and defunct in the Sukinda valley are OMC, BC Mohanty chrome mines, FACOR, IDCOL, IMFA, Balasore alloys, Jindal, TISCO, and Under Ground mines of FACOR. The mining activities were stopped during the pandemic period from 2019-2021. The present status of these mines is given as under ((Epgorissa,2013[37]) :

Odisha Mining Corporation: OMC has three open cast mines in the SUC that started functioning at Kaliapani in 1967 leased with 971.245Ha, South Kaliapani (552.457Ha), and Sukrangi (382.709Ha) from 1980.From 2019 to 2021 production was stopped or scarce due to the COVID-19 pandemic as mines workers stopped working.

***Kaliapani* open cast chromite mines (OMC)** was an opencast mine near the village of Kaliapani started in 1967, leased for971.245Ha (including Forest area 750Ha) was semi-mechanized, with no Chrome Ore Beneficiation (No COB) as on date. However, the tailings and OB excavated and dumped in the area may produce chromium toxicity in the area.

***South Kaliapani* opencast mechanized mine (OMC)**is under started in the year 1980 for a lease period of 20years. The lease period was extended up to 2030. The mine explored till 2019-2020, has explored +10%-40% Cr2O3& +40% Cr2O3. The total lease area put in useunder different heads by FY 2018-19 was 289.746 Ha against the permitted 473.17Ha (applied area 552.457Ha) for use including forest land 416.5Ha. The amount generated from topsoil was 36165 cum and OB of6.61M.cu.m during the year FY 2018-19 without backfilling. OB is dumped ina waste dump (WD1, and WD2), andmineral rejects were stacked inSGD2 to reduce toxicity 20200 nos seedlingsare planned.

Sukrangi chromite mines (OMC);Sukrangi ML granted to M/s Sirajuddin & Co. from 1959 to 1979. After 4 years of mining, in 1963 the Odisha Mining Corporation, GoO) gave a formal grant of the said lease to OMC in 1971 by escalating the mining areabroken by M/s Sirajuddin & Co. Laterin 1978 OMC was extended the granted the ML (Mining Lease) for exploration of chromite's in Sukrangi chromite minesover an area of 382.709 ha for 20 years. OMC operated its mining work from 1980 with a lease area of 382.709ha including forest land of 177.76Ha with Manual open cast operations, No COB, No and little or mine drainage water due to topography. (EIA Study for Expansion of SukrangiChromite Mining Project (OMC)"

Misrilal Mines Private Ltd: The mine is closed and tailings are dumped in the area. It is within the industrial belt, the SPM is higher than the permissible level.

M/s. Balasore Alloys Limited (BAL) Kaliapani Chromite Mine, is a certified company ISO 9001:2008, and ISO 14001:2004 have applied for UG Mining for a lease area of 64.463 Ha for production of 1.692 MTPA chromite ore in 2015, along with ongoing opencast mining which is continued since Sept'2000.

Indian Metals and Ferro alloys Limited IMFA): Topography of SUC taken by IMFA is plain with high undulated ridges of an optimum elevation is 185 m and a minimum is 110mRL with sloping from south to north. Presently a lease area for fully mechanized open-cast mining is allowed for 116.76 ha, from the estimated Band-I reserve of 7.860 MMT (2015). Both open cast and UG mining was proposed in 2015 with a maximum production rate of 6.0LTPA with chrome with a COB plant of capacity 40TPH. The OB and tailings aredumped at an overall slope of maintained at < 30°, (M/S IMFA. EIA/EMP report 2017[40])

Kamara Chromite Mines:is leased to M/s B. C. Mohanty & Sons Pvt Ltd. To augment mining of Chrome Ore from 88,000 TPA to 200000 TPA through COBplant up to 100000 TPA to use also a part of the dump materials. The mining area emerged in 1968 for a mines area of 107.24 Ha.(incl. forest land 5.39Ha)) towards NW of Tamka-Mangalapurroad and periodically lease period has increased and the final year was extended up to 2020. To save the area from mining pollution it has been proposed to utilize effectively the generated wasteof 2095655CuM. (10% for road development, and the rest stored in Dumps) (M/S BC Mohanty and sons project report, 2016[41]).

Saruabil chromite mine:owned by M/S Misrilal Chromite mines hada leased area of 224.633 ha of forestland in the Jajpur district and 22.225 ha of no forest land, the area under the pit is 41.22 ha. The chromite reserve is of 2.931 MMT in 2010-11. The total deposit was 3.934MMT of$Cr_2O_3$of grading of 40 to 52%. Though the mines are closed, the old OB and tailings areimproperly managed withindigenous trees. M/S OMC Ltd has applied to reorganize the mining activity.

M/s Jindal Chromite Mine, Kaliapani, was approved 89.00 ha of forest clearance/ 22.80 ha of lease area (excluding a safety zone of 1.44 ha.) at Kaliapani granted by MoEF, in 2001. Forest diversion has been required for the forest land in the lease area has been changed from 24.240Ha. to 89.00 Ha. At present M/s Jindal Chromite Minehas applied for augmentation of manufacture from 0.10MTPA to 0.215 MTPA. Associated Chrome Ore Beneficiation Plant (COBP) has got environmental clearance to produce60,000 TPA. The mining lease of89.00 ha of forest land has been allotted to M/s Jindal Stainless Limited in 2018. TheMoEF 2018 has stopped mining operations as themine output surpassed the EC approved (M/s Jindal stainless Ltd, 2018[2]).The Cr(VI) conc. the level is much higher than the allowable restrictions in the wastewater.(EGP, Orissa, 2013[37])

Ferro Alloys Corporation Limited (FACOR) a part of Vedanta business in September 2020. FACORcontributes 8% of Indian chrome ore, from three mines (i) The Ostapal Chromite Mines and (ii) Kalaringatta Chromite Mines leased land housed in an area of 72.843 Ha, and 23.800 Ha. But the third one is the Kathapal Chromite Mines, FACOR spread over 113.312Ha. The mines are fully mechanized, with ETP plants to digest hazardous wastes and use Geo-Textiles and strong resistant waterproof material(Silpaulin) for Dump Slope. Now the mines area is having efficient transportation system, use pollution prevention mechanisms, and adequate afforestation, with Health, Safety, and Environment programs for its employees, https://www.facorgroup.in/business/mining/. The continuous mining with human activities has increased to a very higher level of the Cr (VI). The OB pond and the tailing disposal pond overflow may contaminate the geo-bio-hydro and atmosphere of the area. The Cr-VI in air, water, and land is alarming and needs action.

Sukinda Chromite mines(**TISCO**):

Three chromite mining leases were awarded to M/S TISCO, at Sukinda area 116.76 ha of non-forest land having 9.0302 MMT of mineablereserves having total resources of 13.2667 MMT grade averaging 44-46% Cr2O3 in the year 2013. TISCO has applied for a lease of 330.972 Ha forest land in villages Kalaringatta (206.304Ha), Mahulkhal (1.473Ha), and Kaliapani123.195.The 2nd ETP discharging to the Damsala River was 0.1697(which is higher than permitted limits) and water of old quarry pitno 9 was at a level of 1.9685mg/l, which is about 20 times higher. The air quality standard (AQS) is very high near the COB plant at

Ostapal.Drainage discharge near Kalarangi Chowk has increased multifold but the AQS is high but within thresh hold value (Guin et al., 2013).

Tailangi Chromite Mines:

The previous studies indicate the Cr(VI) discharge to the Damsala nallah is at a very high level from tailing ponds, and OB dumps. The outlet of the effluent treatment Plant (ETP) passes through dense human settlement, and the liquid waste discharge has increased and has not been taken care of.

Kamarda Chromite mines

It is leased to M/s B. C. Mohanty & Sons Private Limited, Village: Kamarda, Sukinda for an area of 107.24 Ha. The mines were annexed with (Chrome Ore) from 88,000 TPA to 200000 TPA and Chrome Concentrate through COB Plant up to 100000 TPA by 2016.The Cr+6remains unaltered after the effluent treatment plant and at the nearby village Saruabil mines.

Discussion:

Industrial/anthropogenic accomplishments have up surgedthe toxic pollution of heavy metals mercury (Hg), Lead (Pb), Chromium (Cr), Arsenic (As), and Cadmium, in the environment and undesirably disturb human and plant productivity, metabolism, and growth. in addition to yield.India holds about 2% of the world's chrome ore reserves, with 98% of the resource being concentrated in Odisha Sukinda Valley. The Indian Ferro-chrome industry has traditionally focused on exports due to low domestic demand. However, India's focus on the substantial increase in domestic demand for Ferro-chrome in the future as per capita stainless steel intake rises.

Developing Mining Surveillance System (MSS) with the use of spatialand GIS technology for curbing illegal mining through satellite images overlaid on geo-referenced mining maps, will go a long way in promoting the mining sector and will encourage systematic mining.

Chromium (VI)possibly can be reduced to Cr (III) by using several reductive chemical agents that can be moved out by surface-active adsorbents like Soya cake or Dissolution by LiCl, carbon-nano-Onions (CNOs), Zayed et al., 2003[43], Sinha et al., 2022[44]). High efficiency for the reduction of Cr(VI) to Cr (III)when the value of pH < 1.Various physio-chemical, and biological adaptations for chromium remediation are (i) adsorption by bio-sorption (using $H_2 S$), bio-reduction by $Na_2S_2O_4$, membrane filtration by bioaccumulation ($NaHSO_3$), (iii) nanotechnology by zero-valent iron nanoparticles, Bio-mineralization by electro-dialysis by CAS_5 or reverse Osmosis, [Lindsey et al., 2012[45], Brasili et al, 2020[46], Singh et al., 2021[47], Sharma P, 2022[07])

The friable chromium (Cr VI) ore is carcinogenic. Cr (III), is directly extracted as natural chromite whereas it is converted to the pollutant Chrome VI due to anthropogenic activities(Mishra et al., 2017[48]. Even moderately large doses of Cr (III) may not have any harmful effect, even when ingested through foods by humans or animals. They are excreted in urine and stool. The threshold chromium conc. in water and air is <0.05µgm/lit and 0.1-

0.5mg/m3 respectively, (Sahu et al., 1990). But Cr (VI) is cytotoxic, carcinogenic, and mutagenic beyond the limit. They can create skin ulcers, vomiting, diarrhea, and gastrointestinal bleeding causing cardiovascular shock, (Nayak et al., 2020[49]).

The reduction of Cr (VI) in water, land, and atmosphere and with processes like bioremediation and bio-sorption by micro-organisms membrane separation, adsorption, electro-dialysis, ion exchange, chemical precipitation, use of microorganisms, Nano-technology, Borohydride Exchange Resin and a Polymer-Supported Base and electro-coagulation. The extraction from tailings can be attempted bipolar membrane, (Fatima et al., 2005[50], Liu et al., 2022[51], de Borja et al., 2022[52]).

Ambient air and noise for the people: Plying motorized vehicles and machines have deteriorated ambient air. There is a need for arrangements for the suppression of dust generation nodules. A few measures are wet drilling for UG mining, stamping and crushing in enclosed chambers, application of Wet COB processes, systematic maintenance of roads with regular water sprinkling over tailing dumps, use of dust masks, earmuffs/ ear-plugs, by workers, preparation of green belt surrounding the mines area. For noise control, noise enclosures to noise spawning machines with vibration isolator provisions of the generators, compressors, and pumps, with periodical monitoring of air and noise quality for air/noise pollution.

Food chain adulteration: Geo-bio and hydrosphere of SUCare being contaminated regularly due to mining activities of chromite and iron. The toxic heavy metal Cr-VI level gradually has made it toxic and enters the web of the food chainof micro-organisms and houses in the higher trophic level and finally in the human body causing dysfunctions to their metabolism.

Wildlife in the forest canopy, bio-diversity: The SUC area itself has sparse vegetation and chrome mining activities have added fuel to it. The wildlife, the forests and the biodiversity is being challenged and in jeopardy due to escalated demand for chromite and continued extraction in mines (Dutta et al., 2017[53]).

Needs of the people of the soil:

The minimum following measures will be taken to improvethe quality of life of the people are planting of economically important trees, provision of drinking water, personal hygiene and small dispensary for health care, comfortable approach roads and education to aboriginals of the surrounding villages, preference in skilled and non-skilled jobs, Taking steps to create self-employment opportunities for stakeholders, dump area conversion to afforestation, vegetation and agricultural fields, reduction of soil erosion, Reuse and remediation of the tailings and OB, dug pits to be leveled for not to accumulate water,Groundwork of EIA/EMP at regular intervals and planning to cut milieu deterioration. Retrieval of chromites from waste tailings of SUC is feasible and economic by the magnetic method and multiple reuses in the construction sector, (Khakmardan et al, 2020).

The short-term (need immediate action) and long-term management strategies for a sustained environment and use of the 4R concept (reduce, reuse, recover, and recycle of wastes) need application of its panoramic view nowadays as per SDG 15 (1.1.1) and this path isvery much correct as far as environmental sustainabilityare:

Steadying, remediation and reuse of overburden deposits must be practiced immediately with improvement and upgrading of the road infrastructure which is one of the major lacunae in the connectivity and hinders the mine people's prosperity, though mining activity is age-old and financially lucrative. Dumps should maintain a 20^0 slope.

The benign Cr (III) ion present in chrome ore after its extraction partly transformed to the malignant Cr (VI) in contact with water, air, and soil. The threshold allowable limit should maintain the sustainability of both surface and UG water. The discharging Dumsala Nallah

Frequent monitoring of all drinking water with Cr(VI) as a source excess of the permissible limits to be identified and closedthose showing Cr(VI) in it.

There are some quarries defunct and not leased to any mining company and have OB pits and tailings. Accumulation of seepage in such quarries is an environmentalthreat. Agenciesmust be entrusted with the responsibility for theirpoor management of wastes and to ensure prevention of the untreated accumulated water flowing to nearby water bodies.

The tailings are gradually turning toxic. The Cr (VI) needs to be pumped to the effluent pond or tailing yard by the de-watering system having a screw clarifier/ hydro-cyclone.The water after collectionis required to be sent to a settling pit through an ETP for recycling/reuse. Regular sampling and analyses of the tailings are recorded in the COBP and updated regularly.

The sprinkling of water to the haul roads for dust suppression, and the construction of drains and tailing ponds at strategic points should be prerequisite conditions and mandatory daily reporting to maintain the ambient air quality in the mines area.

As mining of chromite ore involves blasting operations, there is a need to be monitored by seismographs i.e. Minimate, and Minimate Plus, and later analyzed.Noise barriers and noise-less mine machinery should be provided to abate noise pollution (Dutta, et al., 2011[54])

Long Term: The long-term action plan needs to be chalked out and implemented as:

A feasibility report for the required numbers of (zone-wise) common effluent treatment plants(CETP) is required for the mines'liquid waste withmine-wise treatment plants. The zonal CETP shall further reduce the Cr(VI) contentbefore release to the Damsala River. The zero chromium level shall beachieved for the flora and fauna and drinking water of the residents of the area.To stop the conversion of Cr (III) to Cr (IV) plans to be chalked out afforestation and develop a green belt to reduce or remediation of chromium.

To reduce soil erosion from the tailing or OB dumps, where the chance of Cr (VI) generation is high, it is essential to give the regulatory slope to the deposits, with no ponds and pits allowed to accumulate water. Necessary cement concrete drains, effluent treatment plants and ETPs must be maintained properly.

The level of Cr (VI) in the groundwater is not allowed to rise. To safeguard the drinking water of the people and the faunal diversity of the valley, the stormwaterdoes not reach the Damsala nallah, it is highly essential to construct more minor irrigation projects are to be constructed in the upper reaches of the Sukinda valley.

It should be made mandatory to test the physico-chemical properties of surface and groundwater periodically season wise anda time series data to be maintained for future reference and constitution of an expert committee to analyze and to make a sustained biome, human health, and green vegetation.

The leased companies, the Odisha State pollution control board (OSPCB), the central pollution control board, and the mining department have to inspect and monitor the eco-health, and the economic wealth of the state and the nation. They are to be responsible for the deterioration of the geo-bio and hydro environment of the area.

CONCLUSION

The Sukinda Ultramafic Complex belt occurs along the border zone between the iron oresupergroup (IOG) and the Eastern-Ghat Supergroup. This region being Asia's largest workable chromite deposit has become economically viable. The common lithology of the area consists of Precambrian-Ultramafic rock, serpentine, chrome-rich ultramafic, meta-basalt, and gritty to massive quartzite form. In this region, Chromite is deposited in strati form type deposit which exhibits micro-texture such as cumulus compact mosaic, pull apart. Textural studies indicate they are formed by magmatic accumulative differences within the ultramafic pile. Here Dunite and Peridotite from the basement on which the chromite layers were developed.

The expansion of mining has projected that the geo-bio-hydrosphere of the area has chances of chromium contamination so that the entire flora and fauna may be endangered including the inhabitants of the area. It is high time to keep the land, water, and air free from Cr (VI)ions by more afforestation, and the constructionof effluent treatment plants connected by the lined cement drainage system, protecting land erosion to bioremediation against CR (VI) ion. All leaseholders have plants to make the water and soil of the area by adsorption, membrane filtration, nanotechnology, ion exchange, extracellular precipitation, and biomineralization.To save the future Cr (VI) contamination for the sustained life of flora, fauna, and people of the land, pertinent actions are necessary.

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