Risk Assessment and Disaster Management Plan w.r.to Enhancement of production of Saruabil Chromite Mines from 0.136 million TPA to 0.35 million TPA along with Beneficiation Plant of M/s Misrilall Mines Pvt. Ltd., located in village Saruabil in Tehsil Sukinda, District Jajpur of Odisha State (246.858 ha).

A disaster, that befalls can be the cause of nature or manmade. Though science has developed to predict some of the natural disasters and its strength well before its appearance, yet finding ways to prevent them are far at site. Ironically, man-made disasters are well anticipated in its various shapes, sizes and forms. Such manmade disasters are either intentional or un-intentional. Damages caused intentionally by persons either from the internal group or external groups are termed as sabotage. In contrast to the natural disasters, this can be prevented. However, the effects of both types of disasters can be protected if well preparedness for such emergency situations is taken into consideration. With a view to the possibilities and probabilities of such emergency situation into consideration, the DMP is to be descriptively prepared to help and guide the operators of the mining unit in combating such disastrous situations effectively and protecting the lives and properties from a sure and substantial damages.

High risk factors such as landslide, subsidence, flood, fire, tailing dam failure etc. are not encountered or anticipated, but necessary preventive measures and action plan will be taken accordingly.

- In connection with the land slide/Slope failure, a slope stability and slope monitoring study has been carried and by I.I.T., Kharagpur, and found safe mining operation. However, a soil mechanics laboratory has been set up in the leasehold to monitor the soil parameter in connection with slope stability & EDM survey monitoring. Movement pillars are installed and movement survey is carried out by TOTAL STATION equipment regularly. No such occurrence of failure is observed.
- There is no chance of any flood as no river passes within 50 km radius. A small perennial nala is passing adjacent to the northern flank of the lease-hold area. H.F.L. is monitored regularly. However, there is no chance of flooding for the topographical features.
- There is no chance of massive fire. However, for small scale a fire, a trained fire-fighting team with qualified technical persons along with suitable infrastructure is maintained.
- Tailing dam height will be kept not more than 3 mts, so there may not be any chance of failure. The tailing disposal will be a regular practice when tailing will be converted to a cake.

As such, emergency plan for quick evacuation and administrative measure is not proposed at this moment.

Assessment of Risk in Various Mining Operations : Risk assessment is mainly based on the environmental impact of various parameters.

Land Contamination: The potential for contamination during operation of mine site is, waste rock dump which will lead to land contamination.

Aquatic Toxicity: The risk assessment in aquatic toxicity system is based on the total metal concentration in various chemical form or oxidation state. Chromite ore contains the concentration of toxic elements.

Acid Mine Drainage: The mining of Chromite ore does not involve any processing operation by using chemicals. Hence there is no risk at mine site with regard to control of acid mine drainage.

Tailing Dam: Tailings are very fine residuals in the chemical processing operation. It is a potential source of environment contamination. In the Chromite ore mining operation there is no possibility of tailing materials as no chemical process is involved.

Human Health: The chemicals from tailing dam and waste heaps may severely affect the human health. The sulphur contained in the dump can make the land toxic which indirectly affect the human health. During Environment Impact Assessment toxicity was found nil. Hence there is no risk involved to human health due to Chromite ore mining operation.

Factors of risks involved due to human induced activities in connection with mining operations are, removal of O.B and side burden, drilling, blasting, excavation and transportation of ore.

Other factors due to natural activities are Fire, Water inundation, Electricity and Natural calamities

Hazard Control: Maintenance of proper bench geometry, following the precautions will be taken for transport, handling and use of explosives & transport units shall avoid major accidents. In mining operations, the hazardous operations are running of machinery and transportation of minerals storage transportation and use of explosives and slope stability.

Working of the mine as per metalliferous mines regulations and circulars issued by the Director General of Mines Safety from time to time have to be strictly adhered to see that no untoward hazards are encountered.

Biological as well as Health Impact Study w.r.to WHO, ILO & CPCB Norms: Biological as well health impact due to Chromite ore mining are mainly because of Hexavalent Chromium contamination of water bodies. To minimize the impact, mine water including surface runoff has to be treated for Hexavalent Chromium before being discharged outside ML area. There are different treatment methods available as described below to treat Hexavalent chromium. Out of which Ferro Sulphate Reduction Method is adopted in Saruabil Chromite mines of M/s Misrilall Mines Pvt. Ltd.

Treatment of Mine Water and Effluent/toxic substances before Discharge: The Hexavalent parameters before and after treatment in the plant were regularly being monitored in own Environmental laboratory and the result communicated to the concerned authorities. The drinking water had been chlorinated at regular interval in the distribution tank. All season monitoring of drinking water was carried out with special attention to Hexavalent chromium aspect. The result revealed that the water was potable for drinking purpose. Monitoring of both the quarry water and drinking water over all season was carried out in our in-house laboratory.

The water from workshop and garage, which are situated at one place, was allowed to pass through a soaking pit made for the purpose and the contamination free water flowed to the natural drainage.

Hexavalent Chromium treatment of the mine waste water: Chromium is found in two different forms in the Waste streams – Hexavalent chromium and trivalent chromium. Hexavalent chromium is found in mining operations, in the waste streams of plating operations, aluminum anodizing, paint and dye operation, and others industries. Trivalent chromium is found in the waste streams of textile dying, the ceramic and glass industries and photography.

Chromium III is nutritionally essential, nontoxic and poorly absorbed. Deficiency results in glucose intolerance, inability to use glucose and other metabolic disorders. National Academy of Science (NAS), USA estimates safe and adequate intake of 0.05 to 0.20 mg/day.

On the contrary Chromium VI, is toxic, producing liver and kidney damage, internal hemorrhage and respiratory disorders. Sub chronic and chronic effects include dermatitis and skin ulceration. Chromium VI has been shown to cause cancer in humans and animals through inhalation exposure, but it has not been shown to be carcinogenic through ingestion exposure. The USEPA classifies chromium as a human carcinogen (Group A), although the proposed MCLG (Maximum Contaminant Level Goals) and MCL (Maximum Contaminant Level) (for total Chromium) of 0.1 mg/l are based upon non-cancer toxic effects. The WHO and Canadian Guidelines for Drinking Water Quality (1987) , EEC Standards for Parameters Concerning Toxic Sub steams, all mention 0.05 ma/l of chromium as the Maximum Allowable Concentration for total Chromium.

In order to comply with the regulations, technologies were developed and continue to be developed that reduce the concentrations of Chromium (and many other metals) in wastewater effluent to acceptable levels. The technologies currently available to reach the treatment goals have been reviewed in several USEPA documents.

Survey of literature reveals that Chemical Reduction of Hexavalent Chromium from a valence state of +6 to +3 and subsequent hydroxide precipitation of the trivalent chromium is the most common method of Hexavalent chromium disposal. However, to meet increasingly stringent effluent standards, some industries have turned to Ion Exchange to treat chromate and chromic acid wastes. Evaporative recovery of concentrated chromate and chromic acid wastes has also proved technically and economically feasible as a waste treatment alternative.

The application of other methods such as Electrochemical Reduction and Activated Carbon Absorption techniques, have been receiving increasing attention in recent years.

A. ION EXCHANGE: Ion exchange resins, depending upon their chemical nature, show preferential selectivity for specific ions. The greater the affinity of the resin for the absorbed ion, the more complete removal is achieved. However, a high affinity also means greater difficulty in regenerating of the effective resin is difficult it is never carried to completion. As a result the operational capacity of an ion exchange resin may be only 50 – 60% of the theoretical capacity. Ion exchange process are claimed to be economical for Chromium recovery and elimination of waste.

B. CHROMATE DETOXIFICATION/CHROMATE REDUCTION: Most chemical control strategies of chromate detoxification are based on the reduction of Hexavalent chromium (Cr+6) to trivalent chromium (Cr+3). Trivalent chromium is much less toxic than chromates and forms a hydroxide with solubility minimum in the PH range of 8.0 – 9.0. The Common reducing agents are sulphur dioxide, sodium bisulfate, metabisulfite or hydrosulfite, ferrous sulphate and iron sulfide. The trivalent chromium may then be removed, usually by precipitation with lime. The reduction of Hexavalent chromium to trivalent chromium is less than 100% effective, with the amount of residual unreduced Hexavalent chromium depending upon total time of retention allowed for the reduction, pH of the reaction mixture and the concentration and the type of reducing agent employed.

(I) **Chromate Reduction with Sulphur Dioxide**: The most widely used reducing agent for Cr+6 are sulfur dioxide and sodium matabisulfite ($Na_2S_2O_5$). Sulphur dioxide has been most extensively used for the reduction of Chromium wastes, primarily because it is relatively cheep. The dosage of 2.0 kg. SO_2/kg of Hexavalent chromium reduced have been report.

(ii) **Chromate Reduction with Metabisulfite:** Sodium Matabisulfite ($Na_2S_2O_5$) has been extensively used as a reducing agent in many SO_2 based processes. Sodium Metabisulfite crystallizes from solutions containing NaOH and SO_2

in a mole ratio 1:1:1. In aqueous solution it forms an equilibrium concentration with the disulfite ion.

S_2O_5 - + H_2O_5 = $2HSO_3$

Metabisulphite Disculphite

Aqueous solution of sodium metabisulphite react acidicly reducing chromates according to the reaction.

$4H_2CrO_4 + 3\ Na_2S_2O_5 + 6\ H_2SO_4$ ---- $Cr_2\,(SO_4)5 + 6NaHSO_4 = 7\ H_2O$

(III) **Chromate Reduction with Fe^{II} in Acidic medium**: Several reports deal with chromate reduction using ferrous Sulphate, in acidic medium. In most of these and other cases, treatment occurred at steel mills, where waste pickle liquor was available for use in the reduction process.

Theoretically chromate reduction is feasible with ferrous salts in the acidic solutions. The redox potential of Fe III / Fe II chain is pH independent in the acidic region, while the oxidation potential of chromate is strongly dependent on the hydrogen ion concentration, Chromate reducing using ferrous ions in the acid region is preferred at pH values <3. The overall reaction

$2H_2CrO_5 + 6\ FeSo4 + 6H_2SO_4$ ---- $Cr_2(SO_4)_3 + Fe_2(SO_4)_3 + 8H_2O$ consumes 3 moles of Fe11 per mole of Cr+6 reduced to Cr+3. Fe^{II} is ioxidized to Fe^{III} in the reaction.

IV) **Chromate Reduction with Fe^{II} in Alkaline Medium**: Iron II and iron III precipitate in the neutral and alkaline region as hydroxide. The Fe III hydroxide is by 24 orders of magnitude less soluble than the Fe II hydroxide.

Ksp $[Fe(OH)_3]$ = $10^{-37.4}$ whereas

Ksp $[Fe(OH)_2]$ = $10^{-37.8}$

Ksp = Solubility Product

The redox potential of the Fe^{III} / FeII Chain

$E = Eo + RT / F\ 1n\ (a^{III} / a^{II})$ (mV)

Which reduces to $E = 281 - 59 \times pH$ (mV)

The Fe III and Fe II activities are expressed as functions of pH using the solubility product of the hydroxides, the ion product of water (Kw), and the definition of pH.

The potential described by equation (A) is more negative in the entire alkaline range than the oxidation potential of the Cr^{+6} / Cr^{+3} chain. This makes the reduction of chromate feasible in the pH range of 7 – 11. Fe^{II} can be added in the form of ferrous Sulphate, which is a by-product from acid pickling in the steel mills. The Fe^{II} can also be produced electrochemically by anodic dissolution of steel plates.

(V) Chromate Reduction with Iron Sulfide: Chromate can be reduced by the addition of FeS at pH 7, FeII is oxidized to Fe III and the sulphate is oxidized to elemental sulphur.

$H_2CrO_4 + FeS + 2H_2O$ ---- $Cr(OH)_3 + S$

The time needed for the above reaction to proceed to completion is several hours.

(VI) Electrochemical Reduction of Cr^{+6} to Cr^{+3} : Reduction of Hexavalent chromium by the Electrochemical "Cementation" process to trivalent chromium may occur accordingly to the following oxidation-reduction reaction.

$Cr_2O_7 + 3Fe^{+2} + 14H^+$ ---- $2Cr^{+3} + 3Fe^{+2} + 7H_2O$

$Cr_2O_7^{--} + 6Fe^{+2} + 14H^+$ ---- $Cr^{+3} + 6Fe^{+2} + 7H_2O$

The reaction requires acidic condition and is thus pH dependent. Complete reduction of 100 mg/l Cr^{+6} solution has been reported within 8 min at pH = 2.0. In one full-scale application.

Cr^{+6} AT 2.5 – 52.0 mg/l was reduced to 0.01 to 1.40 mg/l by the cementation process. Average influent was 16.3 mg/l and average effluent 0.09 for and average chromate reuction of 89.4%.

(VII) Miscellaneous Process: Absorption on activated carbon has been reported to be a viable method for the removal of chromate from municipal effluent. Initial Hexavalent chromium levels of 0.09 to 0.19 mg/l were reduced to 0.04 mg/l of less.

Reverse Osmosis has also been reported to have application for Hexavalent chromium treatment. However, in addition to pH effect, rate of flux also influence RO performance, with poorer efficiency at higher flux rates.

Technology Assessment and Recommendation : Resources Conservation Recovery Act (RCRA) of USEPA, Corrective Action Proposed Rules: FR 30798127 of July 1990 gives the following environment parameter for chromium in drinking water:

MCLG = 0.1 mg/l

KCL = 0.1 mg/l

RCRA action level = 0.05 mg/kg of Cr^{+6}

The same limiting values are also applicable as per Indian Standards and **MINAS.** Considering the quantity of wastewater generated by the Saruabil Chromite Mines and its chromium content, it is recommended and installed two steps Chromite reduction techniques. Hydraulic rapid mixing (HRM) flume for achieving intense mixing between the waste water and required quantity of Ferrous quantity of Ferrous Sulphate ($FeSo_4$) and NaOH.

Sheer from Hydraulic mixing is used in Flocculator. Aluminum Sulphate is used as Flocculator. The discharge from the reactor – cum Flocculator is fed to an inclined plate clarifier. The effluent standard comes to less than 0.05 mg/l after the treatment.

Considering the above concept an E.T.P. has been set up first in the state at Saruabil Chromite Mines on 18.06.1997, which is working efficiently without any problem.

In the next five years of Scheme period, continuation of the same treatment procedure is proposed. Regular monitoring of the Hexavalent Chromium in treated water will be done in house Environmental Laboratory so that no toxic matter flows with water to pollute the natural water regime.