# SEA NODULES PROCESSING-STATUS REVIEW FOR COMMERCIALISATION

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Manganese nodules represent the largest metal bearing sea bed deposit. Economic evaluation of projects related to multi metal extraction of Cu, Ni, Co & Mn from deep sea nodules have often failed to provide enough incentives to prospective industrial investors for pre-investment planning because of rather high direct costs of metal extraction from sea resources; comparatively, mining & transportation costs for sea nodules are much higher than costs of terrestrial mining / transportation of ores such as nickel laterites. This necessitates recovery of multi metals from sea nodules as compared to recovery of only nickel & cobalt from laterites.

The Indian Program of work considers the manganese recovery option in addition to recovery of Cu,Ni & Co for better process viability & environmental consideration. Three process development approaches have been extensively tested: (a) combined pyro-hydrometallurgical process of reduction roasting and ammoniacal leaching (b) direct leaching process in ammoniacal medium with dissolved sulfur-dioxide as aqueous reducing agents and (c) high temperature reductive sulphuric acid leaching. Manganese is recovered from the specific tailings generated. A pilot plant capable of treating 500 Kgs per day Poly-Metallic Nodules (PMN) was designed and commissioned within the battery limits of a commercial base metal smelting unit. Scale up, basic design, Engineering & Implementation of the pilot plant facilities were based on completely indigenous effort based on the laboratory process data. Up to 92% Ni, 86% Cu & 82% cobalt values have been recovered in continuous trials. A modified silicomanganese smelting process has shown manganese recovery upto 80% at smaller scale; earlier, large scale (300 kg dry residue) smelting trials were conducted using untreated residue with lower recoveries (75%).

Several cost saving technologies were introduced during pilot scale of operation : these include minimization of chemicals for reducing operating cost attained through judicious change of process parameters, process water conservation through hot raffinate wash, reduction of process effluents such as sodium sulphate through the use of state-of-the-art extraction reagents etc.

Indicative techno-economic analyses were carried out for the developed processes. A cost simulation model was developed based on which an estimated nickel price can be estimated for attaining a projected IRR. The current estimates of capital & operating costs for the developed ammoniacal aqueous reduction process for a commercial production facility of 1.5DMTPA with optimized manganese recovery requires a market nickel & cobalt prices of $12/kg & $30/kg which are expected long term projections.

Research programs recently commenced include development of a modified high pressure acid leaching system for Indian nodules for attaining energy economy. Sulfuric acid based

leaching processes are likely to be less energy intensive. Since the requirement of manganese recovery optimization is extremely important for best economic returns, another research program has been initiated to look into direct smelting; the objective is to maximize manganese recovery & minimize Ni, Co & Cu losses. Flow sheet optimization is a mathematical tool which is helpful in analyzing the interplay of different decision variables affecting a process. These decision variables could be grade of nodules, process variables like pressure & temperature, energy required in the process, etc. A study has been initiated for the use of a genetic algorithm based multi objective optimization for nodules processing systems. The optimized flow sheets could then be taken up for use in final flow sheet design.

Collaborative programs could be worked out based on India's recent program thrusts in metallurgy. It would be useful to draw in land based nickel producers in these programs.