Scientific Communications of L.B.Sukla on NANOPARTICLES

1. Biological sequestration and retention of cadmium as CdS nanoparticles by the microalga Scenedesmus-24.

Jayashree Jena, Nilotpala Pradhan , V. Aishvarya, Rati Ranjan Nayak, Bisnu Prasad Dash,Lala Behari Sukla, Prasanna Ku mar Panda, Barada Kanta Mishra, jOURNAL OF APPLIED PHYCOLOGY · DECEMBER 2014 with 65 READS.Impact Factor: 2.56 · DOI: 10.1007/s10811-014-0499-8, pp 1-10.

ABSTRACT: Biological sequestration of cadmium (Cd) and retention of adsorbed cadmium as cadmium sulphide (CdS) nanoparticles inside the cell by a lipid-producing green algae Scenedesmus-24 is reported. The microalga was able to grow in the growth media containing 30 mg L−1 of cadmium without any growth inhibition. Adsorption of Cd(II) was dependent on the pH of the medium, initial concentration of cadmium, density of algal biomass (biosorbent dose), and contact time. The adsorption follows Langmuir isotherm pattern with an estimated maximum cadmium adsorption capacity at 50 mg g−1. The kinetics of adsorption followed Lagergren's pseudo-second-order model. FTIR analysis revealed the presence of different functional groups on the algal biomass which may be responsible for adsorption of Cd(II). After adsorption, the bound metal ions were retained in the microalgal biomass as CdS nanoparticles. Presence of CdS nanoparticle was confirmed by XRD and TEM analysis. The results of the present study conclusively demonstrate that the microalga Scenedesmus-24 may be a promising candidate for sequestration of cadmium from cadmium polluted water and also its recovery as precious CdS nanoparticles.

2. Microalga Scenedesmus sp.: A Potential Low-Cost Green Machine for Silver Nanoparticle Synthesis.

Jayashree Jena · Nilotpala Pradhan · Rati Ranjan Nayak · Bishnu Prasad Das· Lala Behari Sukla· Prasanna Kumar Panda ·Barada Kanta Mishra, Journal of Microbiology and Biotechnology 01/2014; 24(4). DOI:10.4014/jmb.1306.06014 · 1.53 Impact Factor, PP- 522-33.

ABSTRACT: Bionanotechnology has revolutionized the nano material synthesis by providing a green synthetic platform using its biological systems. Among the biological systems microalgae has tremendous potential to uptake metal ions and produce nanoparticle by detoxification process. The present study explores the intracellular and extracellular biogenic synthesis of silver nanoparticles (SNPs) using a unicellular green microalga Scenedesmus. Biosynthesized SNPs were characterized by AAS, UV-Vis spectroscopy, TEM, XRD, FTIR, DLS, TGA studies and finally checked for antibacterial activity. Intracellular nanoparticle biosynthesis is initiated by high rate of Ag(+) ion accumulation in the microalgal biomass and subsequent formation of spherical crystalline SNPS (of average size of 15-20 nm) due to biochemical reduction of Ag(+) ions. The synthesized nanoparticles were intracellular as confirmed by the UV-Vis spectra of experimental medium. Furthermore, extracellular synthesis using boiled extract shows formation of well scattered, highly stable, spherical SNPs with average size of 5-10 nm. Size and morphology of the nanoparticle was confirmed by TEM. Crystalline nature of the SNPs was evident from the diffraction peaks of XRD and bright circular ring pattern of SAED. FTIR and UV-Vis spectra showed that the biomolecules, proteins and peptides, are mainly responsible for formation and stabilization of SNPs. Further, the synthesized nanoparticles exhibited high antimicrobial activity against pathogenic gram negative and gram positive bacteria. Use of such a microalgal system provides a simple, cost effective alternative template for biosynthesis of nanomaterials in large scale system with a great use in biomedical application.

3. Controlled Synthesis of Gold Nanoparticles Using Aspergillus terreus IF0 and Its Antibacterial Potential against Gram Negative Pathogenic Bacteria.

Eepsita Priyadarshini · Nilotpala Pradhan · Lala Behari Sukla ·Prasanna K. Panda · B. K. Mishra , Journal of Nanotechnology 01/2014; Volume 2014, Article ID 653198:PP-1-9. DOI:10.1155/2014/65319.

ABSTRACT: Biosynthesis of monodispersed nanoparticles, along with determination of potential responsible biomolecules, is the major bottleneck in the area of bionanotechnology research. he present study focuses on an ecofriendly, ambient temperature protocol for size controlled synthesis of gold nanoparticles, using the fungus Aspergillus terreus IF0. Gold nanoparticles were formed immediately, with the addition of chloroauric acid to the aqueous fungal extract. Synthesized nanoparticles were characterized by UV-Vis spectroscopy, TEM-EDX, and XRD analysis. Particle diameter and dispersity of nanoparticles were controlled by varying the pH of the fungal extract. At pH 10, the average size of the synthesized particles was in the range of 10–19 nm. Dialysis to obtain high and lowmolecular weight fraction followed by FTIR analysis revealed that biomolecules larger than 12 kDa and having –CH, – NH, and –SH functional groups were responsible for bioreduction and stabilization. In addition, the synthesized gold nanoparticles were found to be selectively bactericidal against the pathogenic gram negative bacteria, Escherichia coli.

4. Biogenic synthesis of floral-shaped gold nanoparticles using a novel strain, Talaromyces flavus.

Eepsita Priyadarshini · Nilotpala Pradhan · Lala Behari Sukla ·Prasanna kumar Panda · Barada Kanta Mishra,Annals of Microbiology September 2014, Volume 64, Issue 3, pp 1055-1063

ABSTRACT: A biogenic route was adopted towards the synthesis of gold nanoparticles using the extract of a novel strain, Talaromyces flavus . Reduction of chloroauric acid by the fungal extract resulted in the production of gold nanoparticle, which was further confirmed by the concordant results obtained from UV–visible spectroscopy, energy dispersive spectroscopy (EDS), and dynamic light scattering (DLS) analysis. Morphology and the crystal nature of the synthesized nanoparticles were characterized using transmission electron microscopy (TEM), X-ray diffraction (XRD) and selected area electron diffraction (SAED). A direct correlation was observed between nanoparticle formation and the concentration of reducing agent present in the fungal extract. The time-dependent kinetic study revealed that the bioreduction process follows an autocatalytic reaction. Crystalline, irregular, and mostly flowershaped gold nanoparticles with a mean hydrodynamic radius of 38.54±10.34 nm were obtained. pH played a significant role on production of mono-dispersed nanoparticle. FTIR analysis partially deciphered the involvement of –NH2, –SH, and –CO groups as the probable molecules in the bio-reduction and stabilization process. Compared to the conventional methods, a time-resolved, green, and economically viable method for floral-shaped nanoparticle synthesis was developed.

5. Biosynthesis And Characterization Of Silver Nanoparticles Using Microalga Chlorococcum Humicola And Its Antibacterial Activity.

Jayashree Jenaa · Nilotpala Pradhana · Bisnu Prasad Dashb · Lala Behari Sukla · Prasanna kumar Panda, International Journal of Nanomaterials and Biostructures 2013; 3(1): 1-8.

ABSTRACT: In the present investigation, synthesis of silver nanoparticles (AgNPs) using fresh extract and whole cell of microalga Chlorococcum humicola was carried out. The extract and the whole cell were incubated with AgNO3. The in-vivo and in- vitro formation of nanoparticles were characterized and investigated by Ultraviolet-Visible (UV-Vis) spectroscopy, Scanning electron microscopy (SEM), Transmission electron microscopy (TEM), Fourier Transform Infrared spectroscopy (FTIR) and X-ray diffraction (XRD). Bioreduction of algal extract showed a gradual change in the colour of the extract due to the formation of silver nanopaticles. The UV-Visible absorption spectrum recorded for the solution shows the distinguishing surface plasmon significance band for silver nanoparticles at 430nm. FT-IR analysis revealed the involvement of protein molecules in the formation of nanoparticles. TEM analysis confirms SNPs formed were 16 nm in size. Further the formed silver nanoparticles showed a strong antibacterial effect on the pathogenic bacteria Escherichia coli. So far, that test organism Chlorococcum humicola has not been reported to mediate nano material biosynthesis, this work confirms the microalga can be used as a suitable system for SNPs synthesis. The bioaccumulation of silver particles makes the organism potential candidate for ecofriendly silver biorecovery system in cost effective manner from industrial wastes.

6. In Situ Synthesis of Entrapped Silver Nanoparticles by a Fungus— Penicillium purpurogenum.

Pradhan Nilotpala; Nayak, Rati Ranjan; Pradhan, Arun Kumar; Sukla, Lala Behari; Mishra, Barada Kanta, Nanoscience and Nanotechnology Letters, Volume 3, Number 5, October 2011, pp. 659-665(7).

ABSTRACT: Intracellular silver nanoparticles are produced by exposing silver nitrate to a fungus—Penicillium purpurogenum. The formation of silver nanoparticles is greatly influenced by the secretion of proteins and more specifically secretion of nitrate reductase enzyme by the fungus. The UV-visible spectra show a broad band at 420 nm for spherical silver nanoparticles. The X-ray diffraction analysis indicates that the structure of the nanoparticles is face centered cubic. Results of transmission and scanning electron microscopy show that the silver nanoparticles are embedded within fungal mycelia. Finally, the biomass embedded nanoparticles are evaluated for their antimicrobial activity. They show significant antimicrobial activity against pathogenic gram negative bacteria likeEscherichia coli and Pseudomonas aeruginosa, and gram positive bacteria like Staphylococcus aureus.

7. Green synthesis of silver nanoparticle by Penicillium purpurogenum NPMF: The process and optimization.

Rati Ranjan Nayak · Nilotpala Pradhan · Debadhyan Behera ·Kshyama Madhusikta Pradhan · Srabani Mishra · Lala Behari Sukla · Barada Kanta Mishra, Journal of Nanoparticle Research August 2011, Volume 13, Issue 8, pp 3129-3137.

ABSTRACT: An eco-friendly microbial method for synthesis of silver colloid solution with antimicrobial activity is developed using a fungal strain of Penicillium purpurogenum NPMF. It is observed that increase in concentration of $AgNO_3$ increases the formation of silver nanoparticle. At 5 mM concentration highly populated polydispersed nanoparticles form. Furthermore, change in pH of the reaction mixture leads to change in shape and size of silver nanoparticles. At lower pH two peaks are observed in the absorption spectra showing polydispersity of nanoparticles. However, highly monodispersed spherical nanoparticles of 8–10 nm size form with 1 mM $AgNO_3$ concentration at pH 8. Antimicrobial activity of nanoparticles is demonstrated against pathogenic gram negative bacteria like Escherichia coli and Pseudomonas aeruginosa, and gram positive bacteria like Staphylococcus aureus. The antimicrobial activity of silver nanoparticles obtained at different initial pH show strong dependence on the surface area and shape of the nanoparticles.

8. Calcium Phosphate Nanoparticles Mediated Gene Therapy for Breast Cancer.

R Mund, N Panda.Amit Biswas,National Institute of Technology Rourkela, Lala Behari Sukla,Council of Scientific and Industrial Research (CSIR), New Delhi, Conference: 2nd International Conference on Tissue Engineering & Regenerative Medicines(ICTERM NOVEMBER 2013), At National Instutute of Technology,Rourkela.

ABSTRACT: Gene therapy is a promising approach to tackle breast cancer. The controlled delivery of genes from biomaterials offers the potential to enhance gene transfer by maintaining an elevated concentration of gene within the cellular microenvironment. Immobilization of the DNA to the substrate to which cells adhere maintains the DNA in the cell microenvironment for subsequent cellular internalization. Calcium phosphate based nanoparticles could be used for cell transfection. The undergoing study evaluates the feasibility and efficacy of using TRAIL gene to treat breast cancer mediated with novel carrier calcium phosphate nanoparticles. These nanoparticles were used as gene carrier to transfect TRAIL gene into MCF-7 cells. The nanoparticles without TRAIL gene were transfected into the tumour cells as negative control. TRAIL gene transfection with liposome as carrier, served as positive control. The apoptosis of cells were detected with TUNEL method. Functionalized nanoparticles of calcium phosphate were developed by mixing aqueous solutions of calcium and phosphate salts and subsequent functionalization of the precipitate with DNA to prevent the aggregation of nanoparticles. These nanoparticles carried a negative charge due to the negatively charged nucleic acids on their surface which enhanced the penetration into breast cancer cells. The nucleic acids provided both electrostatic and steric stabilization of the particles and prevented their aggregation. The particles were characterized by FE-SEM, DLS, Nanotrack analysis and Zeta potential measurement. The synthesized calcium phosphate nanospheres of size 35 to 75 nm loaded with DNA, thus served as an effective therapeutic agent against breast cancer.

9. Potential of microorganisms for Metal nanoparticle bio-synthesis.

Lala Behari Sukla,Council of Scientific and Industrial Research (CSIR), New Delhi, Nilotpala Pradhan,Institute of Minerals and Materials Technology,Eepsita Priyadarshini,Institute of Minerals and Materials Technology, Jayashree Jena,Institute of Minerals and Materials Technology.Conference: 2nd International Conference on Tissue Engineering & Regenerative Medicines (ICTERM NOVEMBER 2013), At National Institute of Technology,Rourkela.

ABSTRACT: Metal nanoparticles and nanostructured materials have found increasing application in the fields of catalysis, electronics, bioremediation, biosensors and also in biomedicines [3, 4]. The boost in use of metal nanoparticles has lead to development of different chemical, physical and biological methods for their synthesis. Physical and chemical methods are the traditional and popularly used methods but they involve the use of energy consuming methods, expensive and hazardous chemicals. This raises environmental concerns and the alternative green technology has emerged as simple and ambient temperature biosynthetic approaches for nanoparticle synthesis by utilizing various biological systems such as bacteria, fungus, plant extracts and algae. We are involved in biosynthesis of metal nanoparticle using fungal and algal system. Focus is on obtaining monodispersed metal nanoparticles both as colloidal solution and matrix bound. These nanoparticles are being tested for applications like antimicrobial activity, phocatalytic activity and biosensing. Apart from these the attempts are being made to identify and understand the role of different biomolecules in nan++oparticle formation and stabilization.

10. Biological route for production of extracellular Gold Nanoparticles using Aspergillus species.

Eepsita Priyadarshini,Institute of Minerals and Materials Technology,Nilotpala Pradhan,Institute of Minerals and Materials Technology.Lala Behari Sukla,Council of Scientific and Industrial Research (CSIR), New Delhi,B.K.Mishra,Conference: International Conference on "Microbial World:Recent Innovations and Future Trends"November22-25,2012.

ABSTRACT: Gold nanoparticles,due to their stability,resistance to oxidation and biocompatibility,have gained particular intrest in fields of electronics,catalysis,sensors and drug delivery systems.The present study aimed at developing a simple, efficient and bio-friendly approach towards biosynthesis of extracellular Gold nanoparticles(GNPs) using fungus. 15 different fungal strains were screened for the production of GNPs, of which two strains, IF-0 and IF-1 , partially identified to be Aspergillus terreus and Aspergillus candidus respectively,were found to be most effective . Both strains were capable of synthesizing GNPs in acomplex cornmeal media, while Asperhillus terreus produced GNPs in simple mineral salt media also. The reaction rate and morphology were found to depend on several parameters like concentration of gold salt (AUCL2) and extracellular fluid(ECF), effect of sucrose and NO3-2 as growth substrate and inducers respectively, PH and temperature. The biosynthesis of nanoparticles was monitored by UV-Vis Spectrophotometer and complemented with characterization using Transmission Electron Microscope. Increase in gold salt(AUCL2) concentration resulted in formation of larger sized nanoparticles with maximum production at 1mM concentration. With increasing ECF concentration,increase in peak intensity was observed. Sucrose in the growth media was found to significantly enhance the formation of monodispered GNPs.

11. Biosynthesis of Silver Nano Particle Using Microorganisms.

Nilotpala Pradhan,Institute of Minerals and Materials Technology,Pratima kumari Mishra,Institute of Minerals and Materials Technology,Lala Behari Sukla,Council of Scientific and Industrial Research (CSIR), New Delhi, In book: Mineral Biotechnology, Publisher: Director, Regional Research Laboratory, Bhubaneswar, Editors: B.K. Mishra, L.B. Sukla, K. Srinivasa Rao, pp.332-337 National Seminar on Mineral Biotechnology,RRL Bhubaneswar,January 30-31, 2007.

ABSTRACT: Synthesis of nano materials with help of biological systems like microorganisms is now considered important towards development of environment friendly green technology.Extra-cellular production of metal nano particles by filamentous fungus isolated from uranium mine is attempted. Aqueous silver ions when exposed to the fungal metabolites released in the culture filtrate, forms a stable silver hydrosol. This hydrosol show spectral absorbance pattern similar to that of silver nano metal hydrosol. The silver nano particles are in the range of 20 to 50 nm size and homogenously scattered in the medium. The process being extra cellular may lead to the development of a rational and easy bioprocess for synthesis of silver nano particle.

Scientific Communications of L.B.Sukla on nickel

1. Enhanced recovery of nickel from chromite overburden (COB) using Dissimilatory Fe (III) reducers: A novel Bio-Reduction Acid Leaching (BRAL) approach.

Jacintha Esther, Institute of Minerals and Materials Technology, Dr. Sandeep Panda, T.C. Süleyman Demirel Üniversitesi, Lala Behari Sukla, Council of Scientific and Industrial Research (CSIR), New Delhi, Tondepu Subbaiah, Institute of Minerals and Materials Technology, ***ARTICLE*** *in HYDROMETALLURGY ,APRIL 2015, Impact Factor:1.93· DOI:10.1016/j.hydromet.2015.04.019.*

ABSTRACT: The nickeliferous Chromite overburden (COB) awaits a suitable technology to extract the obstinate nickel ingrained in its goethite matrix. In the present study, a novel Bio-Reduction Acid Leaching (BRAL) approach has been proposed using dissimilatory iron reducing bacteria (DIRB) which is inherently capable of transforming iron mineral phases via bio-reduction (BR). Mineralogical characterization of the bio-reduced COB using XRD and FTIR confirmed the phase transformation of goethite to hematite and magnetite with exposure of the nickel oxide peaks. Further, morphological characterization using FESEM vividly highlighted the changes of acicular goethite to granular magnetite deposits on the extra polymeric substance (a scaffold for electron transfer) secreted by the DIRB consortium over the surface of COB. Further, enhanced nickel extraction was achieved with a reductive acid leaching (AL) approach with 6 N sulphuric acid and 2% glucose (reducing agent) at 65 °C for 6 h. A cumulative of 83.6% nickel was achieved through this BRAL approach. The pregnant leach solution (PLS) generated as a result of the AL approach was subjected to the hydrometallurgical route to recover metallic nickel. Solvent extraction (SX) of the PLS was performed using 0.5 M NaD2EHPA as extractant. The pregnant nickel-loaded electrolyte was subjected to electrowinning (EW) to recover metallic nickel of 99.6% purity. The process flow-sheet is believed to provide a suitable eco-friendly, potential method to efficiently extract nickel from low grade nickel laterites to meet the ever growing demands caused by depletion of high grade nickel sulphidic ores.

2. DEVELOPMENT OF BIO-PROCESS FOR NICKEL METAL RECOVERY FROM NICKELIFEROUS CHROMITE OVERBURDEN.

Jacintha Esthera,Lala Behari Sukla,Council of Scientific and Industrial Research (CSIR), New Delhi, Nilotpala Pradhana,Tondepu Subbiah DECEMBER 2014. Conference: NATIONAL SEMINAR ON VISION -2020 FOR METALLURGICAL INDUSTRIES, At Bhubaneswar.

ABSTRACT: Nickeliferous chromite overburden (COB) in the Sukinda Valley of Odisha containing 0.7-1% nickel awaits a suitable process methodology to extract the valuable metals ingrained in their mineral phases. The conventional pyro- and hydro- metallurgy methods consume intense energy, require high capital investments, cause environmental hazards, etc., thus becoming industrially and environmentally unfeasible. Employing microorganisms towards biotechnological means of extraction may overcome the above downsides. A group of microorganisms called 'dissimilatory iron reducing bacteria (DIRB) inherently reduce Fe3+ to Fe2+ coupled to oxidation of organic carbon source for their energy and growth requirement. Hence, in the first step of present study, COB of 5% pulp density was subjected to biological pre-treatment using DIRB capable of transforming the mineral phase (Goethite Hematite, Magnetite) at 1L scale. In second step enhanced nickel recovery was achieved◊ by reductive acid leaching of the bioreduced COB with glucose as the organic reducing agent in sulphuric acid. A total of 88.8% nickel was recovered from the nickeliferous COB subjected to bio-reduction and reductive acid leaching. Nickel was recovered from leach solution through solvent extraction using Na2DHPA as extractant in the third step. Finally,

electrowinning of the nickel laden aqueous phase obtained a metallic nickel deposit with 99.6% purity. Hence, in this study, an efficient and eco-friendly process is proposed involving bioreduction, acid leaching, solvent extraction and electrowinning (BR-AL-SX-EW).
Keywords: Nickeliferous chromite overburden, Dissimilatory iron reducing bacteria, Flowsheet

3. Diversity of Dissimilatory Iron Reducing Bacteria and their utilization for enhanced nickel extraction from Chromite Overburden.

Lala Behari Sukla,Council of Scientific and Industrial Research (CSIR), New Delhi,Jacintha Esther,Institute of Minerals and Materials Technology, Nilotpala Pradhan,Institute of Minerals and Materials Technology,Barada Kanta Mishra AUGUST 2013 Conference: INTERNATIONAL CONFERENCE ON CONSERVING BIODIVERSITY FOR SUSTAINABLE DEVELOPMENT((INCCBSD 2013),At NATIONAL INSTITUTE OF TECHNOLOGY,Rourkela.

ABSTRACT: Microorganisms are a scientific asset as they remarkably orchestrate life on earth. Microorganisms play a significant role in the various cycles of terrestrial and aquatic ecosystems. Specific microbes from the ancient Precambrian age have key impact in the biogeochemical cycles of carbon and iron due to their immense metabolic versatility. They possess the unique ability to utilize a wide range of soluble electron acceptors such as nitrate, nitrite, sulphur, trimethylamine N-oxide, dimethyl sulfoxide as well as insoluble oxidized metals such as iron and manganese, various radionuclides like uranium, plutonium, etc. Of these, the dissimilatory iron reducing bacteria (DIRB) has found widespread attention due to their ability to reduce Fe (III) as sole electron acceptor coupled to the oxidation of organic carbon source (electron donor) under anerobic/facultative anaerobic conditions. This ability of DIRB was exploited in our study to extract nickel and cobalt from chromite overburden (COB). Nickel is engrained within the goethite phase of COB which restrains its release, thus rendering conventional leaching methods inefficient. A phase change of this ore to its reduced form of hematite and magnetite can loosen the matrix, enhancing the extraction efficiency. COB reduction through thermal activation by roasting at high temperatures, through reduction-magnetic separation process with activated carbon powder as the reductant , solid-state deoxidisation method utilise an energy intensive approach makes it more uneconomic and less eco-friendly. Hence, nickel extraction using microbes has gained interest in the recent past. Several studies have focused on bioleaching of COB using fungi and chemolithotrophs. These microbial processes have exhibited issues of low extraction efficiency, laborious downstream processing due to substantial fungal biomass, and tedious requirement of pH maintenance in case of chemolithotrophs. Here, we subjected the COB to microbial reduction using DIRB followed by acid leaching for enhanced nickel-cobalt recovery. Various DIRB consortia were isolated from different marshy areas and screened the consortia capable of efficiently reducing Fe (III) of Chromite overburden (COB) under facultative anaerobic condition. DIRB was found to liberate the goethite-associated nickel as a result of the phase change in ore during its growth. The phase change was confirmed by XRD analysis, wherein the goethite and hematite peaks were observed in original COB while DIRB-treated COB showed a nickel oxide and magnetite peaks in addition to goethite and hematite. The phase change is pertained to the microbial reduction of Fe (III) to Fe (II). Morphological study using FESEM showed a variance from needle shaped goethite in original ore to granular magnetite in treated ore. About 27% nickel was obtained on bio-reduction of COB which was enhanced by 43% on treating with 8M sulphuric acid, resulting in 70% Ni recovery.

4. Effect of dissimilatory Fe (III) reducers on bio-reduction and nickel-cobalt recovery from Sukinda chromite-overburden.

Jacintha Esther,Institute of Minerals and Materials Technology,Dr. Sandeep Panda,T.C. Süleyman Demirel Üniversitesi,Dr. Sunil Kumar Behera,University of Johannesburg,Barada K Mishra, BIORESOURCE TECHNOLOGY • JULY 2013,CSIR-Institute of Minerals and Materials Technology, Bhubaneswar, Odisha 751013, India,Impact Factor: 4.49 · DOI: 10.1016/j.biortech.2013.07.103 · Source:

ABSTRACT: The effect of an adapted Dissimilatory Iron Reducing bacterial consortium (DIRB) towards bio-reduction of Sukinda Chromite overburden (COB) with enhanced recovery of nickel and cobalt is being reported for the first time. The remarkable ability of DIRB to utilize Fe (III) as terminal electron acceptor reducing it to Fe (II) proved beneficial for treatment of COB as compared to previous reports for nickel leaching. XRD studies showed goethite as the major iron-bearing phase in COB. Under facultative anaerobic conditions, goethite was reduced to hematite and magnetite with the exposure of nickel oxide. FESEM studies showed DIRB to be associated with COB through biofilm formation with secondary mineral precipitates of magnetite deposited as tiny globular clusters on the extra polymeric substances. The morphological and mineralogical changes in COB, post DIRB application, yielded a maximum of 68.5% Nickel and 80.98% Cobalt in 10 days using 8M H2SO4.

5. Recovery of nickel from chromite overburden, Sukinda using Aspergillus Niger supplemented with manganese.

Dr. Sunil Kumar Behera,University of Johannesburg,Prangya Parimita Panda,Sandeep Kumar Saini,Utkal University, Bhubaneshwar, India, Lala Behari Sukla,Council of Scientific and Industrial Research (CSIR), New Delhi. KOREAN JOURNAL OF CHEMICAL ENGINEERING 30(2):392-399 · FEBRUARY 2013 ,Impact Factor: 1.17 · DOI: 10.1007/s11814-012-0142-9.

ABSTRACT: Oxalic acid is a prominent metabolite secreted by several fungi under specific conditions, which acts as a metal chelating agent. Amongst different fungal species, Aspergillus niger is favored as the best option for microbial production of oxalic acid. The present study deals with the oxalic acid over production by A.Niger in response to man-ganese supplement to its growth medium, which in turn improves the recovery of nickel from pre-treated chromiteoverburden(COB) during fungal bioleaching. The metabolic pathway in oxalate bio-synthesis by A.Niger involves one prominent cytoplasmic enzyme oxaloacetate acetylhydrolase (OAH), which catalyzes the breakdown of oxaloacetate metabolic intermediate to oxalate and acetate. Oxalic acid production was increased due to supplement of manganeseo the culture medium of the A.Niger . Manganese acts as cofactor for OAH enzyme; further, it enhances the catalytic of OAH to produce more oxalate. With oxalic acid production by A.Niger nickel recovery from pre-treated COB was improved. During the study, a maximum of nickel recovery was achieved up to 38.6% from pre-treated COB by adding 80 ppm of manganese to the culture media, whereas 24.0% of nickel was recovered without supplement of manganese (experiments were performed at 30 o C and the COB pulp density 2% w/v).

6. Microbial Recovery of Nickel from Lateritic (Oxidic) Nickel Ore.

Lala Behari Sukla,Council of Scientific and Industrial Research (CSIR), New Delhi,Dr. Sunil Kumar Behera,University of Johannesburg,Nilotpala Pradhan,Institute of Minerals and Materials Technology. In book: Geomicrobiology and Biogeochemistry,Series: Soil Biology,, Edition: Vol. 39, Publisher: Earth System Sciences,Springer, Editors: Parmar, Nagina; Singh, Ajay (Eds)

7. Biological Extraction of Nickel, A Value Added Metal from Chromite Overburden.

Jacintha Esther,Institute of Minerals and Materials Technology,Lala Behari Sukla,Council of Scientific and Industrial Research (CSIR), New Delhi,Nilotpala Pradhan,Institute of Minerals and Materials Technology,Barada Kanta Mishra. DECEMBER 2012 Conference:NATIONAL SEMINAR ON WASTE TO WEALTH.

ABSTRACT: Great concern exists for the management of large quantities of overburden generated by opencast chromite mining in Sukinda Valley, Odisha. Chromite overburden (COB) has been reported to contain low-grade nickeliferous laterite which requires a suitable technology to extract the value added metal. Bioleaching methods using indigenous micro-organisms have gained focus for this extraction as the hydrometallurgical and pyrometallurgical methods are energy and cost intensive. Nickel is well-associated with the ferric form of iron present in the laterite which results in less recovery by nominal process. Dissimilatory iron reducing bacteria (DIRB) reduce the ferric of COB, eventually causing a phase change and exposing the nickel for higher recovery. Pre-treatment of COB with DIRB consortia has been studied followed by acid leaching for enhanced nickel recovery. Acid-digestion of COB revealed the presence of 1% nickel. In XRD study, goethite and hematite peaks were observed in untreated ore while DIRB-treated ore showed magnetite peaks in addition to goethite and hematite peaks which confirm the reduction of iron. FESEM images show the variance of morphology from needle shaped goethite in original ore to granular magnetite in treated ore. 27% Ni was recovered from acid-wash of treated ore which was enhanced to 69% on acid-leaching of treated ore. Hence, treatment of COB with DIRB can enhance the recovery of nickel.

8. Microbial Extraction of Nickel from Chromite Overburdens in Presence of Surfactant.

Dr. Sunil Kumar Behera,University of Johannesburg, Lala Behari Sukla, Council of Scientific and Industrial Research (CSIR), New Delhi. TRANSACTIONS OF NONFERROUS METALS SOCIETY OF CHINA 22(11) · NOVEMBER 2012 ,CSIR-Institute of Minerals & Materials Technology, Bhubaneswar 751013, India,Impact Factor: 1.18 · DOI: 10.1016/S1003-6326(11)61540-9.

ABSTRACT: The effect of surfactant polyoxyethylenesorbitan monolaurate (Tween-20) on the nickel bioleaching from pre-treated chromite overburden (COB), Sukinda with fungal strain Aspergillus niger, was examined in shake flasks. Along with the nickel recovery from COB by the fungal bioleaching, the effect of surfactant on the growth of the A. niger was also investigated. Results show that the addition of surfactant in low concentration was favorable for the recovery of nickel from pre-treated COB. Normally, the carbon source (sucrose) in the culture medium was utilized by the A. niger for its cellular metabolism and organic metabolites (bio acids) were produced, which were responsible for the bioleaching of minerals. However, the addition of surfactant (Tween-20) accelerated the rate of sucrose consumption by the fungi, and thus enhancing the extraction of nickel from pre-treated COB. During the study, around 39% nickel extraction was achieved in A. niger mediated bioleaching performed at 2% pulp density of pre-treated COB at 30 °C, in the presence of surfactant whereas only 24% nickel was extracted without surfactant.

9. Extraction of nickel by microbial reduction of lateritic chromite overburden of Sukinda, India.

Dr. Sunil Kumar Behera,University of Johannesburg,Sandeep Kumar Panda,University of Johannesburg,Nilotpala Pradhan,Institute of Minerals and Materials Technology, Lala Behari Sukla, Council of Scientific and Industrial Research (CSIR), New Delhi,B K Mishra. BIORESOURCE TECHNOLOGY 125C:17-22 • AUGUST 2012 Institute of Minerals and Materials Technology (CSIR), Bhubaneswar 751 013, India.Impact Factor: 4.49 • DOI: 10.1016/j.biortech.2012.08.076 •

ABSTRACT: Microbial extraction of nickel from lateritic chromite overburden (COB), Sukinda by Acidithiobacillus ferrooxidans has been investigated in this work. In anoxic environment, A. ferrooxidans reduced the ferric iron in goethite [Fe(O)OH] mineral of COB by using elemental sulphur as electron donor. Nickel embedded in the complex goethite matrix of COB was successfully recovered by cumulative action of sulphuric acid, generated by oxidation of elemental sulphur and reduction of ferric iron in goethite matrix by A. ferrooxidans. Forty one percent of the nickel present in COB was extracted in a 3L scale bioreactor (pH of 1.8±0.05, temperature of 28±2°C) maintained in anoxic environment. In contrast, only 11% of the nickel present in COB was extracted with continuous supply of air to the bioreactor keeping all the parameters unchanged. Kinetics study of anoxic microbial processing of COB revealed that the chemical reaction rate control model fits to the rate of nickel dissolution (R(2)=0.975).

10. Study on reaction mechanism of bioleaching of nickel and cobalt from lateriticchromite overburdens.

Dr. Sunil Kumar Behera,University of Johannesburg,P. P. Panda,Dr. Sradhanjali Singh,National Environmental Engineering Research Institute-Delhi Zonal Laboratory, Nilotpala Pradhan,Institute of Minerals and Materials Technology ,Lala Behari Sukla, Council of Scientific and Industrial Research (CSIR), New Delhi,B. K. Mishra. INTERNATIONAL BIODETERIORATION & BIODEGRADATION 65(7):1035-1042 • SEPTEMBER 2011 Institute of Minerals & Materials Technology (CSIR), Bhubaneswar 751 013, India,Impact Factor: 2.13 · DOI: 10.1016/j.ibiod.2011.08.004

ABSTRACT: Depletion of high-grade ores and presence of significant quantities of metals in low-grade oxide ores has enforced to utilize the overburdens (COB) and wastes (low-grade ores) generated during mining operations. The impact of ore mineralogy and mineral–microbe interaction during bioleaching could not be ignored. Seeking to the need, a systematic study was performed to establish the reaction mechanism involved for recovery of nickel and cobalt from chromite overburden (COB), Sukinda, Orissa using pure culture of Aspergillus

niger. Mineralogical analysis reveals a complete conversion of goethite into hematite phase leading to exposure of nickel particles into the micro-pores and cracks developed in the matrix which was initially found to be intertwined in the goethite lattice. As a result, it became more susceptible to attack by the fungal bio acids which in turn accelerate the dissolution rate. Organic acids like oxalic and citric acids were detected in the culture filtrate using HPLC. TEM analysis of the leached samples shows that nickel dissolute into the solution leaving a porous space in the matrix of the hematite by forming nickel oxalate or nickel citrate. Kinetics of the nickel bioleaching was studied to support the mechanism of the reaction. It was observed that the initial rate of reaction follows the chemical control dissolution reaction where as the later part fits to shrinking core model. 18% of nickel and 37.8% of cobalt was recovered from pre-treated COB at 2.5% pulp-density with 10% (v/v) fungal inoculum at 30 °C within 25 days in shake flask while 32.5% of nickel and 86% of cobalt was recovered in bioreactor.

11. Microbial Recovery of Nickel and Cobalt from Pre-treated Chromite.

Dr. Sunil Kumar Behera,University of Johannesburg, Prangya Parimita Panda,Lala Behari Sukla, Council of Scientific and Industrial Research (CSIR),New Delhi. JANUARY 2011 . Recent Research in Science and Technology 3(6) 2011 page-28-33.

ABSTRACT: Aspergillus niger exhibits good potential in generating a variety of metal chelating and solubilization organic acids during cellular metabolism. In this context, the minor constituent metals like nickel and cobalt embedded in chromite overburdens (COB) of Sukinda mines have been exploited through bio-hydrometallurgical route for recovery of these metal values. XRD and EPMA analysis of COB reveals that initially nickel was intertwined in the goethite lattice while after pre-treatment (600oC), due to phase conversion of goethite to hematite leads to exposure of nickel particles into the micro-pores and cracks developed in the matrix. Hence, becoming more susceptible to attack by the fungal bio acids and accelerates metal dissolution. At a pulp density of 2 % (w/v) of pre-treated COB maximum nickel and cobalt recovered were 33.2 % and 82.4 % respectively after 24 days in shake flasks bioleaching using A. niger.

12. Study on reaction mechanism of bioleaching of Nickel and Cobalt from lateritic chromite overburdens.

Dr. Sunil Kumar Behera,University of Johannesburg,P.P.Panda,Dr. Sradhanjali Singh,National Environmental Engineering Research Institute-Delhi Zonal Laboratory, Nilotpala Pradhan,Institute of Minerals and Materials Technology, Behari Sukla,Council of Scientific and Industrial Research (CSIR), B. K. Mishra.JANUARY 2011 „ International Biodeterioration and Biodegradation, 65,7- 1041-1048.

ABSTRACT: Depletion of high-grade ores and presence of significant quantities of metals in low-grade oxide ores has enforced to utilize the overburdens (COB) and wastes (low-grade ores) generated during mining operations. The impact of ore mineralogy and mineral–microbe interaction during bioleaching could not be ignored. Seeking to the need, a systematic study was performed to establish the reaction mechanism involved for recovery of nickel and cobalt from chromite overburden (COB), Sukinda, Orissa using pure culture of Aspergillus niger. Mineralogical analysis reveals a complete conversion of goethite into hematite phase leading to exposure of nickel particles into the micro-pores and cracks developed in the matrix which was initially found to be intertwined in the goethite lattice. As a result, it became more susceptible to attack by the fungal bio acids which in turn accelerate the dissolution rate. Organic acids like oxalic and citric acids were detected in the culture filtrate using HPLC. TEM analysis of the leached samples shows that nickel dissolute into the solution leaving a porous space in the matrix of the hematite by forming nickel oxalate or nickel citrate. Kinetics of the nickel bioleaching was studied to support the mechanism of the reaction. It was observed that the initial rate of reaction follows the chemical control dissolution reaction where as the later part fits to shrinking core model. 18% of nickel and 37.8% of cobalt was recovered from pre-treated COB at 2.5% pulp-density with 10% (v/v) fungal inoculum at 30 °C within 25 days in shake flask while 32.5% of nickel and 86% of cobalt was recovered in bioreactor.

13. Leaching of nickel laterite using fungus mediated organic acid and synthetic organic acid: A comparative study.

Behera, S K and Sukla, L B and Mishra, B K (2010) . In: Proceedings of the XI International Seminar on Mineral Processing Technology (MPT-2010), Dec 2010, NML Jamshedpur, India.

ABSTRACT: A huge amount of overburden (nearly 8 to 10 times of the ore) containing trace amount of nickel and cobalt is generated during Chromite mining at Sukinda valley, Orissa, Chromite overburden contains around 0.4 to 0.9% Ni and 0.02 - 0.05% Co respectively. The setting up of nickel and cobalt processing plant based on these deposits through conventional methods such as pyrometallurgy and hydrometallurgy is not economical. The microbes and metals interaction have been studied for the exploitation in metals extraction. So an attempt has been made to extract these metals using multi metal resistant indigenous microorganisms, isolated from the Chromite overburden of Sukinda mines. A native strain of Aspergillus species was used for bioleaching. Aspergillus species are well known for their potential to produce a variety of organic acids (oxalic, citric acids etc.). The mineralogical studies indicated that there is no separate nickel bearing mineral phase in the Sukinda Chromite overburden. The mineralogy of the raw lateritic ore reveals the presence of goethite, ferrihydrites as major minerals. In the thermally activated overburden the minerals present were hematite, surimarite, quartz and traces of magnetite. Experiments were carried out with synthetic organic acids at 2.5% pulp density, 350C and 150rpm. Synthetic oxalic acid (0.1M) leached 5% Ni and 71% Co from raw ore, whereas it leached 43% Ni and 95% Co from thermally activated ore. Citric acid (0.1M) was not that much efficient. It leached 9% Ni and 14% Co from raw ore and 32% Ni and 45% Co from thermally activated ore. The fungal culture filtrate leached 3% Ni and 12% Co from raw ore. In case of roasted ore it leached 18% Ni and 28% Co at 2.5% pulp density, 350C and 150rpm. Mineralogical analysis was carried out through X-ray diffraction, FTIR and transmission electron microscopy.

14. MICROBIAL REDUCTION OF LATERITIC NICKEL ORE FOR ENHANCED RECOVERY OF NICKEL AND COBALT THROUGH BIOHYDROMETALLURGICAL ROUTE.

Lala Behari Sukla,Council of Scientific and Industrial Research (CSIR), New Delhi,B.K. Mishra,Nilotpala Pradhan,Institute of Minerals and Materials Technology, B.D. Nayak. FEBRUARY 2009 ,DOI: 10.13140/2.1.3692.1286 ,In book: TMS 2009 138th Annual Meeting & Exhibition. Linking Science and Technology for Global solutions, Chapter: Energy Technology Perspective, Publisher: TMS (The minerals, Metals & Materials, Society), 2009, pp.213-224.

ABSTRACT: Present study is about use of a group of Iron[Fe(III)] Reducing Bacteria (IRB) to convert the goethite (α FeOOH) present in the original lateritic Nickel ore to magnetite under an anaerobic condition and subsequently release the bound Co(III) and Ni(II) through leaching. The lateritic Nickel ore contains 0.8% Ni, 0.049% Co, 1.92% Cr, 0.32% Mn and 50.2% Fe. An anaerobic dissimilatory Fe(III) reducing bacterial consortium capable of using acetate as carbon source (electron donor) and lateritic ore as terminal electron acceptor, changes the initial light brown color of the ore to dark brown. The change in color is due to the conversion of goethite to magnetite, which was confirmed by XRD. When the IRB treated sample was subjected to both bioleaching and acid leaching, it shows a greater recovery of Nickel and Cobalt values as compared to untreated original lateritic Ni ore. Further a magnetic separation method was used to separate the magnetic part of the treated lateritic ore and subjected to acid- and bio-leaching for better recovery of Nickel and Cobalt.

15. Recovery of nickel from lateritic nickel ore using Aspergillus niger and optimization of parameters.

S. Mohapatra,Nilotpala Pradhan,Institute of Minerals and Materials Technology,3rd Swati Mohanty,Institute of Minerals and Materials Technology,Lala Behari Sukla,Council of Scientific and Industrial Research (CSIR), New Delhi. MINERALS ENGINEERING 22(3):311-313 • FEBRUARY 2009 ,Institute of Minerals and Materials Technology (CSIR), BMBT, Jaydev Vihar, Bhubaneswar 751013, Orissa, India,Impact Factor: 1.60 · DOI: 10.1016/j.mineng.2008.08.002 .

ABSTRACT: The present study deals with the extraction of nickel from lateritic nickel ore of Sukinda mines, Orissa, through microbial leaching using Aspergillus niger. The presence of significant metals in oxidic nickel

ores, are potential sources of nickel for the future. Thus, experiments were carried out with ore to optimize the conditions for maximum nickel recovery. Experiments designed as per central composite design technique, were carried out for fitting an empirical reduced second order model. The factors studied were sucrose concentration, pulp density, temperature and duration. In addition to main effects of four factors, sucrose concentration, pulp density and duration had quadratic effect on the percentage extraction and there were interactions between different factors also. There was also significant interaction between temperature and duration as well as sucrose and pulp density. The F-value for the model shows that model is significant at less than a 0.01% level (i.e. at 99.99% confidence level). The predicted maximum nickel extraction was 31.34% with a pulp density of 8.75%, sucrose concentration of 10.04 g/l, temperature 33.8 °C and duration of 37.5 days.

16. Nickel recovery from chromite overburden of Sukinda using fungal strains.

Bohidar Sagarika, Mohapatra S, Lala Behari Sukla,Council of Scientific and Industrial Research (CSIR), New Delhi. INTERNATIONAL JOURNAL OF INTEGRATIVE BIOLOGY 5(2) · JANUARY 2009.

ABSTRACT: The primary objective of this study is to develop a feasible and cost-effective technique for microbial recovery of nickel from chromite overburden of Sukinda, Orissa. In this study, the feasibility of recovery of nickel from a low-grade chromite overburden was attempted by employing three fungal strains Aspergillus niger, Aspergillus fumigatus and Penicillium species. Comparison of leaching studies using ore (unroasted) and roasted ore was carried out. Also in-situ and culture filtrate leaching experiments were compared. The adapted fungal strains showed better leaching results as compared to the unadapted strains. The in situ nickel leaching ability of a laboratory stock culture of fungus Aspergillus niger show maximum leaching of 34% nickel with roasted material at 2% pulp density, 30o C and 150rpm after 28 days incubation, while 32% nickel was solubilised by A.fumigatus under the same conditions.

17. Biological leaching of nickel and cobalt from lateritic nickel ore of Sukinda mines.

Smaranika Mohapatra,Chandan Sengupta, Bansi Dhar Nayak,Barada Kanta Mishra. KOREAN JOURNAL OF CHEMICAL ENGINEERING 26(1):108-114 · JANUARY 2009 ,Impact Factor: 1.17 · DOI: 10.1007/s11814-009-0017-x .

ABSTRACT: In the present study lateritic nickel ore was used for bacterial leaching using a mixed consortium of mesophilic acidophiles.The microorganisms were adapted to 1 gram nickel/L prior to leaching. For the experiments, lateritic ore in different forms such as raw, roasted, roasted ore presoaked in dilute sulphuric acid and palletized pretreated roasted (400 °C and 600 °C) ore were taken. The leaching experiments were conducted in 9 K+ with 40 L capacity bioreactor using 10% (v/v) inoculum concentration at 10% (w/v) pulp density. The aeration was maintained at 2–3 L/min and the speed of agitator and temperature at 400–500 rpm and 35 °C. The maximum extraction of nickel and cobalt was observed with pretreated ore (600 °C) at 10% pulp density (77.23% and 73.22%) respectively within 31 days at pH 1.5 and least extraction in case of raw ore i.e., 9.47% nickel and 41.12% cobalt respectively.

18. Effect of thermal pretreatment on recovery of nickel and cobalt from Sukinda lateritic nickel ore using microorganisms.

Smaranika Mohapatra, Chandan Sengupta, Bansi Dhar Nayak, Barada Kanta Mishra. KOREAN JOURNAL OF CHEMICAL ENGINEERING 25(5):1070-1075 · SEPTEMBER 2008 ,Impact Factor: 1.17 · DOI: 10.1007/s11814-008-0175-2.

ABSTRACT: Experimental investigation made previously on microbiological leaching of nickel and cobalt from the laterite nickel ore of Sukinda Valley reveals that the recovery was not very much promising under any favorable conditions. Therefore, in order to improve the efficiency for bioleaching, the homogenized lateritic ore in palletized form is thermally pretreated by roasting at different temperatures. The parameters studied for the bioleaching experiments were the four types of pretreated ore which were roasted at different temperatures, i.e., 300 °C, 400 °C, 600 °C and 800 °C, in shake flask by using a mixed mesophilic acidophilic bacterial consortium consisting predominantly of the Acidithiobacillus ferrooxidans strain. It was observed that the pretreated ore at 600 °C with 10% (w/v) pulp density showed maximum recovery of nickel and cobalt, i.e., 59.18% (4.556 ppm)

and 65.09% (0.546 ppm), using 10% (v/v) (2.5 × 108 cells/ml) consortium concentration at 1.5 pH, 30 °C, and 150 rpm after an incubation period of 31 days.

19. Microbial extraction of nickel from Sukinda chromite overburden by Acidithiobacillus ferrooxidans and Aspergillus strains.

S. Mohapatra,S. Bohidar, Nilotpala Pradhan ,Lala Behari Sukla), HYDROMETALLURGY 85(1):1-8 · JANUARY 2007

ABSTRACT: In this study, the recovery of nickel from a low-grade chromite overburden was attempted by employing two fungal strains, Aspergillus niger and Aspergillus fumigatus, and a mixed culture of mesophilic acidophiles (predominantly Acidithiobacillus ferrooxidans). Various factors were studied for bioleaching of chromite overburden such as, temperature, pH and pulp density. It was found that the At. ferrooxidans culture solubilized nickel effectively at temperatures ranging from 30 °C to 37 °C, whereas the organism was not able to solubilize nickel at higher temperatures, such as 45 °C. The use of higher pulp density resulted in a decrease of the percent nickel recovery whereas lower pulp density resulted in higher recovery values. Besides, increased supplemental ferrous iron increased the leaching efficiency of the At. ferrooxidans culture. The maximum nickel solubilization was 40%, at 2% pulp density, and 24%, at 10% pulp density, at 30 °C after 28 days leaching at 150 rpm.In the case of fungal strains, a comparison of leach ability of chromite overburden and roasted overburden was made. The factors studied were pulp density and reaction time. The adapted fungal strain showed better leaching results as compared to the unadapted strains. The in situ nickel leaching efficiency of a laboratory stock culture of A. niger showed maximum recovery of 34% nickel with roasted chromite overburden, at 2% pulp density, while 32% nickel was solubilized by A. fumigatus, under the same conditions at 30 °C and 150 rpm, after 28 days incubation.

20. Bioleaching of lateritic nickel ore by ultrasound.

Rabi Narayan Kar,Central Drug Research Institute, Lala Behari Sukla,Council of Scientific and Industrial Research (CSIR), New Delhi, K M Vinayaka Swamy,Sir M. Visvesvaraya Insititute of Technology,K. L. Narayana. METALLURGICAL AND MATERIALS TRANSACTIONS B 27(3):351-354 · JUNE 1996 ,Impact Factor: 1.46 · DOI: 10.1007/BF02914897.

ABSTRACT: The bioleaching of nickel from lateritic ore of Orissa, India, using a nativeAspergillus niger strain was studied with and without ultrasound. Different parameters, such as spore concentration, amount of dextrose in the medium, pulp densities, and sonication time, were studied for maximizing the extraction of nickel. Enhanced recoveries and reduction in leaching time were demonstrated using ultrasound. The highest amount of nickel, 95 pct, was extracted in 14 days with an inoculum size of 106 spore/mL and 2 pct dextrose in the medium under 30 minutes ultrasonic pretreatment using 43 KHz frequency at 1.5 W/cm2 intensity. It was also found that ultrasound assists in selective leaching of nickel over iron.

21. Use of ultrasound in microbial leaching of nickel from laterites.

K M Vinayaka Swamy,Sir M. Visvesvaraya Insititute of Technology, Lala Behari Sukla,Council of Scientific and Industrial Research (CSIR), New Delhi,K.L. Narayana,V.V. Panchanadikar. ULTRASONICS SONOCHEMISTRY 2(1):S5-S9 • MAY 1995 ,Regional Research Laboratory, Bhubaneswar-751 013, India,Impact Factor: 4.32 · DOI: 10.1016/1350-4177(94)00003-B .

ABSTRACT: The importance of ultrasound in nickel extraction from lateritic nickel ore using a strain of Aspergillus niger was studied. The parameters examined were the pulp density, the ratio of length to diameter () of an ultrasonic cell, ultrasonic frequency and intensity and duration of exposure. The optimum conditions for maximum nickel extraction were a pulp density of 8.7% with an ultrasonic cell having an ratio of 0.75 using an ultrasound frequency of 20 kHz at an intensity of 1.5 W cm−2 while the sample was exposed for 30 min. Ultrasound enhanced the leaching rate of nickel and maximum extraction of 95% nickel was obtained in 14 days, in contrast to 24.9% nickel with conventional in situ bioleaching. It was found that in the presence of A. niger ultrasound had a significant effect, because it enhanced the growth of organisms resulting in an increased extraction rate of nickel with selective leaching of nickel over iron. This beneficial effect may possibly be due to a

combination of leachant pore penetration, boundary and product layer breakdown and localized temperature increase and growth of microorganisms.

22. Bioleaching of copper converter slag using Aspergillus niger isolated from Lateritic Nickel Ore.

Lala Behari Sukla,Council of Scientific and Industrial Research (CSIR), New Delhi, Rabi Narayan Kar,Central Drug Research Institute. PANCHANADIKAR V. V. INTERNATIONAL JOURNAL OF ENVIRONMENTAL STUDIES 47(2):81-86 · FEBRUARY 1995 ,DOI: 10.1080/00207239508710947 .

ABSTRACT: Bioleaching of copper converter slag of MIS Hindustan Copper Limited, Ghatsila, India, was carried out using a strain of Aspergillus niger isolated from the Sukinda Lateritic Nickel Ore. The organism was enriched in 2% potato dextrose broth prior to leaching in the same medium with different solid to liquid ratios by varying dextrose concentration from 2-10%. Control (without organism) was kept under identical conditions to determine the background level of leaching. Positive control experiments with oxalic, acetic and succinic acids (IM) were also done. Experimental and control flasks were incubated at 37° on a rotary shaker for 72 hours. The maximum leaching of Cu, Co and Ni was found to be 47, 50 and 23% respectively, at 2% solid liquid ratio. Of the three organic acids tested, succinic acid was found to be relatively better in leaching out the metals. Increase of dextrose concentration increased the metal recovery at the same solid: liquid ratio. Findings are discussed for the use of heterotrophic microorganisms in mineral bioleaching.

23. Bioleaching of lateritic nickel ore using Penicillium species.

Lala Behari Sukla,Council of Scientific and Industrial Research (CSIR), New Delhi, Rabi Narayan Kar, Central Drug Research Institute, V.V. Panchanadikar,S. Choudhury and R.K. Mitra ,Transactions of Indian Institute of Metals Vol 48 No.2 JANUARY 1995, page-103-106.

ABSTRACT: Bioleaching of Sukinda lateritic nickel ore was carrie out using a species of filamentous fungus Penicillium.The parameters examined were pulp density(2-20%),dextrose concentration in the leaching medium(2-10%) and size fraction(-44 to-350BSS).Under optimimum condition this fungus could leach a maximum of 90% cobalt,40% Mn and 12.5% nickel indicating selectivity of former two metals.

24. Effect of ultrasonic irradiation on bioleaching of Sukinda nickel ore.

K.L. Narayana, K M Vinayaka Swamy,Sir M. Visvesvaraya Insititute of Technology, V.V. Panchanadikar,Lala Behari Sukla, Council of Scientific and Industrial Research (CSIR), New Delhi. Acoustics Letters Vol 18 No.12, year-JANUARY 1995, page-227-232.

ABSTRACT: Studies on bioleaching of nickel from lateritic nickel ore with the use of an ultrasonic pre-treatment resulted in shortening of leaching time while maximising the yield. The studies showed that in 14 days, 95% nickel was leached, which was more than the previous results of Tarasova et al. (1993) who have obtained only 35% nickel from Greece laterites over the same period. The present study indicated that a combination of continuous wave ultrasound for longer sonication up to 30min at 1.5w/cm2 intensity should be preferred over short bursts of high intensity ultrasonics of 120s at 7W/cm2. The beneficial effects of ultrasound are probably due to combination of pore penetration facilitated by the lixiviant, and boundary layer breakdown, as shown by scanning electron micrographs.

25. A process for the recovery of copper, nickel cobalt from converter slag through bacterial method.

Lala Behari Sukla,Council of Scientific and Industrial Research (CSIR), New Delhi, Rabi Narayan Kar, Central Drug Research Institute, V. V. Panchanadikar, JANUARY 1994 . Proceedings of International Symposium on Beneficiation, Agglomeration and Environment (ISBAN-99), Bhubaneswar, 20-22, January-1999 ,page-216-221.

26. Bioleaching of lateric nickel ore using a heterotrophic micro-organism.

Lala Behari Sukla ,Council of Scientific and Industrial Research (CSIR), New Delhi, Vinita Panchanadikar. HYDROMETALLURGY 32(3):373-379 · APRIL 1993,Regional Research Laboratory, Bhubaneswar 751 013, Orissa, India,Impact Factor: 1.93 · DOI: 10.1016/0304-386X(93)90048-I.

ABSTRACT: The nickeliferous lateritic ore of Sukinda, Orissa (India) is a complex ore containing very fine particles. An attempt has been made to leach nickel using indigenous microflora, which were isolated from the same ore. It was observed that 90% of nickel and 34% cobalt were extracted from the lateritic nickel ore. The percentage of dextrose in the growth medium was varied from 2% to 10% in order to increase the nickel extraction. Organic acids such as oxalic and citric acid and acids generated by microbial metabolism were also used for leaching. The results were compared with those of microbial leaching.

The nickeliferous lateritic ore of Sukinda, Orissa (India) is a complex ore containing very fine particles. An attempt has been made to leach nickel using indigenous microflora, which were isolated from the same ore. It was observed that 90% of nickel and 34% cobalt were extracted from the lateritic nickel ore. The percentage of dextrose in the growth medium was varied from 2% to 10% in order to increase the nickel extraction. Organic acids such as oxalic and citric acid and acids generated by microbial metabolism were also used for leaching. The results were compared with those of microbial leaching.

The nickeliferous lateritic ore of Sukinda, Orissa (India) is a complex ore containing very fine particles. An attempt has been made to leach nickel using indigenous microflora, which were isolated from the same ore. It was observed that 90% of nickel and 34% cobalt were extracted from the lateritic nickel ore. The percentage of dextrose in the growth medium was varied from 2% to 10% in order to increase the nickel extraction. Organic acids such as oxalic and citric acid and acids generated by microbial metabolism were also used for leaching. The results were compared with those of microbial leaching.

27. Microbial leaching of lateritic nickel ore.

Lala Behari Sukla,Council of Scientific and Industrial Research (CSIR), New Delhi, V V Panchanadikar,Rabi Narayan Kar ,Central Drug Research Institute. WORLD JOURNAL OF MICROBIOLOGY AND BIOTECHNOLOGY , vol 9(2), page 255-7 ,MARCH 1993, Regional Research Laboratory,Impact Factor: 1.78 · DOI: 10.1007/BF00327850 · Source:

ABSTRACT: Lateritic nickel ore from the Sukinda Mines, Orissa, India, was leached using Thiobacillus ferrooxidans, Bacillus circulans, Bacillus licheniformis and Aspergillus niger at 5% (w/v) solid: liquid ratio for 5-20 days. Maximum leaching of Ni was achieved with B. circulans (85%) and Aspergillus niger (92%) after 20 days. Bacillus circulans showed significantly higher rate of leaching than the other organisms giving 80% Ni extraction after 15 days. The importance and usefulness of heterotrophic organisms in metal extraction are discussed.

28. Kinetics of nickel dissolution from roasted laterites.

Lala Behari Sukla,Council of Scientific and Industrial Research (CSIR), New Delhi, R. P. Das, HydroMet Proc,Name of the Journal -Transactions of Indian Institute of Metals, Vol 40 ,year- AUGUST1987 ,Page 351-353.

ABSTRACT: It has been demonstrated that around 360 degree C the transformation of goethite to hematite takes place. The aim of this work was to see whether during such transformation, the leaching kinetics of nickel and iron has been affected and if so, how the leaching behavior from laterites has changed. Leaching with sulfuric acid was carried out to elucidate possible reaction mechanisms both before and after the goethite to hematite transformation.

29. Recovery of Cobalt, Nickel and Copper from Converter Slag through Roasting with Ammonium Sulphate and Sulphuric Acid.

Lala Behari Sukla,Council of Scientific and Industrial Research (CSIR), New Delhi, S.C. Panda,P.K. Jena. HYDROMETALLURGY 16(2):153–165 · JUNE 1986,Regional Research Laboratory, Bhubaneswar 751013, Orissa India,Impact Factor: 1.93 · DOI: 10.1016/0304-386X(86)90040-X.

ABSTRACT: Roasting of copper converter slag containing 4.03% copper, 1.98% nickel and 0.48% cobalt with ammonium sulphate open to atmosphere has been carried out in order to achieve sulphation of copper, nickel and cobalt followed by leaching of the metal values as soluble sulphates with water. The effect of parameters such as temperature (200–600°C), time (15–120 min), and amount of ammonium sulphate (0.5–2.5 times stoichiometric) has been studied. Under atmospheric conditions, using 2.5 times the stoichiometric requirement of ammonium sulphate, the recovery of copper, nickel and cobalt was found to be 85%, 81% and 85%, respectively. Similar studies were carried out with sulphuric acid. The influence of experimental variables such as the amount of sulphuric acid (0.25–2 times stoichiometric), roasting temperature (100–300°C) and time (15–120 min) has been studied. Under optimum conditions, i.e., at 150°C and a roasting time of 60 min with the stoichiometric amount of sulphuric acid, recoveries of copper, nickel and cobalt were 95, 90 and 99%, respectively, along with a contamination of 60–80% iron. Removal of most of the iron from the leach liquors has been effected with ammonia liquor and lime as precipitants. A two-stage roasting operation using sulphuric acid, first at 150°C and then at 650°C, has resulted in bringing the iron content down to about 3% in the sulphation product without much affecting the recovery of other metal value.

Scientific Communications of L.B.Sukla on Copper Bioleaching

1. Sequential bioreduction - bioleaching and bioreduction - chemical leaching hybrid tests for enhanced copper recovery from a concentrator ball mill reject sample.

Sandeep Panda, Jacintha Esther, Tilothama Bhotra, Nilotpala Pradhan, Lala Behari Sukla, Barada Kanta Mishra and Ata Akcil , ARTRICLE in HYDROMETALLURGY VOL - 157, 2015,PP-171-177.

ABSTRACT: Dumping of poor but metal containing industrial waste is associated with several environmental issues. Exposure of these wastes to the natural environment offers serious concerns for the mineral processing industries to utilize them for metal recovery and check environmental pollution. In the present study, a novel sequential bioreduction–bioleaching and bioreduction–chemical leaching route as a hybrid process is compared and discussed for the enhanced recovery of copper from an industrial concentrator plant ball milling unit rejected sample. A mixed consortium of metal reducing bacteria (DMRB) initially adapted to high Fe(III) concentrations was found to cause mineralogical/matrix alteration (possibly silicate weathering) including Fe(III) bioreduction in the sample and dissolute 29.73% copper during the first 35 days under facultative anaerobic conditions. Sequential leaching of the bioreduced waste sample (generated from the first step) using a mixed meso-acidophilic bacterial consortium predominantly Acidithiobacillus ferrooxidans showed additional 28.72% copper dissolution within 2 days using 1 gL− 1 Fe(II). On the other hand, a comparative chemical leaching of the same bioreduced sample using 0.5 M H2SO4 yielded additional 32.17% copper within 4 days of leaching and indicated better performance than the bioleaching tests. Hydrometallurgy,157,2015,171-177.

2. Reductive dissolution by waste newspaper for enhanced meso-acidophilic bioleaching of copper from low grade chalcopyrite: A new concept of biohydrometallurgy.

Sandeep Panda, Avijit Biswal, Srabani Mishra, Prasanna Kumar Panda, Nilotpala Pradhan, Umaballava Mohapatra, Lala Behari Sukla, Barada Kanta Mishra and Ata Akcil, Hydrometallurgy Volume 153, March 2015, Pages 98–105

ABSTRACT: Dumping of low-grade chalcopyrite encompasses several environmental problems. Despite slow dissolution rate, meso-acidophilic bioleaching is preferred for the extraction of copper from such ores. In the present study, meso-acidophilic bioleaching of a low-grade chalcopyrite in the presence of an acid-processed waste newspaper (PWp) is discussed for the first time. The study illustrated a strong catalytic response of PWp with enhanced bio-recovery of copper from acid-conditioned chalcopyrite. A maximum of 99.13% copper recovery (0.36% Cu dissolution/day) was obtained in 6 days of bioleaching in the presence of 2 gL^{-1} PWp in contrast to only 5.7% copper in its absence. FTIR analysis of bioleached residues revealed similar spectral patterns to the original acid-conditioned ore in the presence of PWp, thus indicating less development of passivation layer which was also confirmed through a complementary Raman characterization of the bioleached residues. Further, a reaction mechanism (chemistry) was proposed suggesting the possible role of PWp as the electron donor under oxygen limiting conditions which facilitated microbial reduction of Fe (III). The resulting biochemical changes provided an energy source for the bacteria, thus allowing free flow of electrons through the ore surface, thus contributing towards enhanced bioleaching of copper.

4. Bio-beneficiation of iron ore using heterotrophic micro-organisms, Sitharashmi Sahu, Madhushree Kundu, Lala Behari Sukla

3.Bioleaching of copper from pre and post thermally activated low grade chalcopyrite contained ball mill spillage.

S. Panda, N.Pradhan, U.Mohapatra, S. K. Panda, S. S. Rath, D. S. Rao, B.D.Nayak, L. B. Sukla, B. K. Mishra, Research Article Frontiers of Environmental Science & Engineering April 2013, Volume 7, Issue 2, pp 281-293

ABSTRACT: Bioleaching of a low grade chalcopyrite (ball mill spillage material) was tested for copper recovery in shake flasks. The original samples (as received) were thermally activated (600°C, 30 min) to notice the change in physico-chemical and mineralogical characteristics of the host rock and subsequently its effect on copper recovery. A mixed culture of acidophilic chemolithotrophic bacterial consortium predominantly entailing Acidithiobacillus ferrooxidans strain was used for bioleaching studies and optimization of process parameters of both original and thermally activated samples. Mineralogical characterization studies indicated the presence of chalcopyrite, pyrite in the silicate matrix of the granitic rock. Field emission scanning electron microscopy coupled with Energy dispersive spectroscopy (FESEM-EDS) and X-ray Fluorescence (XRF) analysis indicated mostly SiO2. With pH 2, pulp density 10% w/v, inoculum 10% v/v, temperature 30°C, 150 r$min–1, 49% copper could be recovered in 30 days from the finest particle size (– 1 + 0.75 mm) of the original spillage sample. Under similar conditions 95% copper could be recovered from the thermally activated sample with the same size fraction in 10 days. The study revealed that thermal activation leads to volume expansion in the rock with the development of cracks, micro and macro pores on its surface, thereby enabling bacterial solution to penetrate more easily into the body, facilitating enhanced copper dissolution.

4. Bioleaching of copper from pre and post thermally activated low grade chalcopyrite contained ball mill spillage

Sandeep PANDA, Nilotpala PRADHAN, Umaballav MOHAPATRA, Sandeep K. PANDA, Swagat,S. RATH, Danda S. RAO, Bansi D. NAYAK, Lala B. SUKLA, Barada K. MISHRA, Research Article Frontiers of Environmental Science & Engineering April 2013, Volume 7, Issue 2, pp 281-293

ABSTRACT: Bioleaching of a low grade chalcopyrite (ball mill spillage material) was tested for copper recovery in shake flasks. The original samples (as received) were thermally activated (600°C, 30 min) to notice the change in physico-chemical and mineralogical characteristics of the host rock and subsequently its effect on copper recovery. A mixed culture of acidophilic chemolithotrophic bacterial consortium predominantly entailing Acidithiobacillus ferrooxidans strain was used for bioleaching studies and optimization of process parameters of both original and thermally activated samples. Mineralogical characterization studies indicated the presence of chalcopyrite, pyrite in the silicate matrix of the granitic rock. Field emission scanning electron microscopy coupled with Energy dispersive spectroscopy (FESEM-EDS) and X-ray Fluorescence (XRF) analysis indicated mostly SiO2. With pH 2, pulp density 10% w/v, inoculum 10% v/v, temperature 30°C, 150 r$min–1, 49% copper could be recovered in 30 days from the finest particle size (– 1 + 0.75 mm) of the original spillage sample. Under similar conditions 95% copper could be recovered from the thermally activated sample with the same size fraction in 10 days. The study revealed that thermal activation leads to volume expansion in the rock with the development of cracks, micro and macro pores on its surface, thereby enabling bacterial solution to penetrate more easily into the body, facilitating enhanced copper dissolution.

5. Heap bioleaching of chalcopyrite: A review

N. Pradhan , K.C. Nathsarma, K. Srinivasa Rao, L.B. Sukla, B.K. Mishra, Minerals Engineering , Volume 21, Issue 5, April 2008, Pages 355–365

ABSTRACT: Bioleaching is an emerging technology with significant potentials to add value to the mining industries so as to deliver attractive environmental and social benefits to all the associates. Chalcopyrite, CuFeS2, is the most important copper-bearing mineral in the world and unlike many other ores it is known to be recalcitrant to hydrometallurgical processing. The main hindrance to the commercial application of biohydrometallurgical processing of chalcopyrite is its slow rate of dissolution. In this piece of review work, the microbiological and other important aspects of chalcopyrite heap bioleaching processes are discussed. The modest nutritional requirements of bioleaching organisms may be provided with the aeration of iron- and/or sulfur-containing mineral suspensions in water or the irrigation of a heap, while working in a large scale. This chemolithotrophic metabolism makes the organisms industrially important. The emphasis is given on the biodiversity of microbial community and the factors affecting heap bioleaching. The cost of bio heap leaching in respect of some existing commercially operating heap

bioleaching plants is also included. Application of chalcopyrite bioleaching in heap/dump leach processes can potentially result in lower cost and reduced environmental impact in copper production.

6. Insights into heap bioleaching of low grade chalcopyrite ores — A pilot scale study

S. Panda a, K. Sanjay a, L.B. Sukla a, N. Pradhan a, T. Subbaiah a, B.K. Mishra a, M.S.R. Prasad b, S.K. Ray b, Hydrometallurgy Volumes 125–126, August 2012, Pages 157–165

ABSTRACT: Heap bioleaching of low grade chalcopyrite (CuFeS2) was carried out in 1000 tons scale over a time period of 383 days. Bacterial solution was prepared and re-circulated in specially designed BACFOX (BACterial Film OXidation) tank. The micro-organisms used in the pilot scale were a mixed culture of acidophilic bacteria predominantly of the Acidithiobacillus ferrooxidans strain. Effect of rest period, solution recirculation, acid concentration, frequency of solution transfers and seasonal effects on copper recoveryweremonitored. The leaching studies showed a cumulative copper dissolution rate of 0.14% per day (2.37 kg d−1). The overall recovery of the heapwas 30%. Variation in leaching efficiency and some of the precautionary measures to improve performance of heap bioleaching are also discussed.

7. Bio-dissolution of copper from Khetri lagoon material by adapted strain of Acidithiobacillus ferrooxidans

Mousumi Mishra, Sradhanjali Singh, Trupti Das, Rabi Narayana Kar,,Karanam Srinivasa Rao, Lala Bihari Sukla and Barada Kanta Mishra, Biotechnology Korean Journal of Chemical Engineering May 2008, Volume 25, Issue 3, pp 531-534

ABSTRACT: Bioleaching involves the use of iron and sulfur oxidizing microorganisms to catalyze the dissolution of valuable metals. In this investigation, lagoon material contains 0.39% Cu, in which the major copper bearing mineral is chalcopyrite associated with other minerals present as minor phase. Leaching experiments were carried out using an adapted strain of Acidithiobacillus ferrooxidans with various parameters such as presence/absence of iron, pH, pulp density and temperature. Base of the medium was 9 K (without ferrous) Bio-dissolution of copper was found to be maximum, i.e., 80.9% with 9 K+ (with ferrous) at pH-2.0, 10% pulp-density and 35 oC within an incubation period of 30 days.

8. Bio-hydrometallurgical processing of low grade chalcopyrite for the recovery of copper metal

Sandeep Panda, Chinmaya Kumar Sarangi, Nilotpala Pradhan, Tondepu Subbaiah, Lala Behari Sukla,Barada Kanta Mishra, Gur Lal Bhatoa, Mullukutlashivram Prasad, and Subrat Kumar Ray Environmental Engineering Korean Journal of Chemical Engineering June 2012, Volume 29, Issue 6, pp 781-785.

ABSTRACT: A process flowsheet was developed to recover copper metal from the lean sulfide ore of copper available at Malanjkhand, Hindustan Copper Limited (HCL), India. Copper pregnant leach solution (PLS) obtained from bio-heap leaching of chalcopyrite containing 0.3% copper was purified through solvent extraction (SX) and the copper recovered by electrowinning (EW). The copper-free raffinate obtained from SX stripping unit was returned back to the bioleaching circuit. The purity of the electrolytic copper produced at pilot scale was found to be 99.96%. During electrowinning, the effect of flow rate of electrolyte on current efficiency and energy consumption was also studied.

9. Extraction of copper from bacterial leach liquor of a low grade chalcopyrite test heap using LIX 984N-C

S. Panda a,c, P.K. Parhi b, N. Pradhan a, U.B. Mohapatra c, L.B. Sukla a, K.H. Park b, Hydrometallurgy Volumes 121–124, June 2012, Pages 116–119.

ABSTRACT: Low grade copper ore (ball mill spillage) obtained from Malanjkhand Copper Mine was processed through heap bioleaching at pilot scale. Bioleach liquor (Pregnant Leach Solution) from the heap contains (g/L of) Cu (II) 0.45, Fe (III) 0.838, Zn (II) 0.006, Ni (II) 0.0014, Mn (II) 0.011 and Pb (IV) 0.004. Solvent extraction of copper from Pregnant Leach Solution was carried out using LIX 984N-C. Effect of different operational factors such as equilibrium pH (pHe), extractant concentration, strip solution concentration, phase ratio was examined to optimize the condition for selective and quantitative extraction of copper. Based on the results of extraction as well as stripping isotherm, a 6-cycle counter current simulation study (CCS) was conducted for the conformational study. The extraction of copper was quantitative in 2-stages using 1.5% (v/v) LIX 984N-C at A: O ratio of 1:2 and pHe 1.85. The CCS condition (two stages, phase ratio A:O=1:4) obtained from the stripping isotherm study, further attributes to the enrichment (4 folds) of copper concentration in the strip solution.

10. Extraction of Copper from Malanjkhand Low-Grade Ore by Bacillus stearothermophilus

Sradhanjali Singh , Lala Behari Sukla ,Baroda Kanta Mishra, Indian Journal Of Microbiology, Jan 26 2011,51(4):477-81.

ABSTRACT: Thermophilic bacteria are actively prevalent in hot water springs. Their potential to grow and sustain at higher temperatures makes them exceptional compare to other microorganism. The present study was initiated to isolate, identify and determine the feasibility of extraction of copper using thermophilic heterotrophic bacterial strain. Bacillus stearothermophilus is a thermophilic heterotrophic bacterium isolated from hot water spring, Atri, Orissa, India. This bacterium was adapted to low-grade chalcopyrite ore and its efficiency to solubilize copper from Malanjkhand low-grade ore was determined. The lowgrade copper ore contains 0.27% Cu, in which the major copper-bearing mineral is chalcopyrite associated with other minerals present as minor phase. Variation in parameters such as pulp-density and temperatures were studied. After 30 days of incubation, it was found that Bacillus stearothermophilus solubilize copper up to 81.25% at pH 6.8 at 60_C.

11. Structural Modification of Chalcopyrite Ore for Enhanced Copper Recovery

Sradhanjali Singh, Bansi Dar Nayak, Rama Chandra Mohanty, Swaranjit S. Cameotra, Lala Beheri Sukla and Dong-Jin Kim4,+ ,Materials Transactions, Vol. 53, No. 11 (2012) pp. 2004 to 2010.

ABSTRACT: Malanjkhand copper project, Madhya Pradesh, India, generates a lot of lean sulphidic ores containing chalcopyrite (^{3}0.3% of copper) with traces of oxidized, semi-oxidized and secondary sulfides. EPMA analysis shows that the granitic rock samples have plagioclase feldspar,orthoclase feldspar and quartz as major constituents within which the ore minerals are sparsely distributed. Due to the complex structure and low solubility of the sulphide-bearing granitic rock, the dissolution of copper from the hard matrix is difficult. The present study deals with change in crystallographic and chemical nature of the mineral system present in the host rock. In an attempt to increase copper recovery, the ore was subjected to heating at 600°C under normal atmospheric conditions. This heat treatment resulted in enhanced copper recovery, up to 98% within 60 days of progressive leaching.

12.Differential bioleaching of copper by mesophilic and moderately thermophilic acidophilic consortium enriched from same copper mine water sample

N.P. Marhual, N. Pradhan , R.N. Kar, L.B. Sukla, B.K. Mishra Bioresource Technology 99 (2008) 8331–8336

ABSTRACT: Three acidophilic enrichment consortium were developed from mine water sample of copper mine site at Khetri, India were compared for their copper leaching efficiency. Out of these one was mesophilic (35 _C) and two were moderately thermophilic (50 _C). Consortia were named as mesophilic acidophilic chemolithotrophic consortia (MACC), thermophilic acidophilic chemolithotrophic consortia (TACC), and Sulfobacillus acidophilic consortia (SAC). Copper extraction ability of both the thermophilic consortia (77–78% extraction) was almost double to that of mesophilic consortia (40% extraction) at 10% pulp density after 55 days. Both the thermophilic consortia were equally effective in leaching of other metals like Ni, Co, Zn, Mn. After 55 days, the percentage of extractions of copper by TACC was 76, 74, 67, 48 and 45 at 5%, 10%, 15%, 20% and 30% pulp density, respectively. Total number of bacteria was maximum at 5% pulp density which decreases with increase in pulp density. Sulfobacillus-like bacteria were seen in the Sulfobacillus enrichment cultures. Moderately thermophilic consortia proved to be better in leaching performance than the mesophilic counterpart.

13.Bioleaching of copper converter slag using Aspergillus niger isolated from Lateritic Nickel Ore

L. B. Sukla , R. N. Kar & V. V. Panchanadikar International Journal of Environmental Studies 02/1995; 47(2):81-86. DOI: 10.1080/00207239508710947

ABSTRACT: Bioleaching of copper converter slag of MIS Hindustan Copper Limited, Ghatsila, India, was carried out using a strain of Aspergillus niger isolated from the Sukinda Lateritic Nickel Ore. The organism was enriched in 2% potato dextrose broth prior to leaching in the same medium with different solid to liquid ratios by varying dextrose concentration from 2-10%. Control (without organism) was kept under identical conditions to determine the background level of leaching. Positive control experiments with oxalic, acetic and succinic acids (IM) were also done. Experimental and control flasks were incubated at 37° on a rotary shaker for 72 hours. The maximum leaching of Cu, Co and Ni was found to be 47, 50 and 23% respectively, at 2% solid liquid ratio. Of the three organic acids tested, succinic acid was found to be relatively better in leaching out the metals. Increase of dextrose concentration increased the metal recovery at the same solid: liquid ratio. Findings are discussed for the use of heterotrophic microorganisms in mineral bioleaching.

Scientific Communications of L.B.Sukla on Microalgae

1.Large scale cultivation of brackish water isolates Scenedesmus sp. in raceway pond for biodiesel production

Lala Behari Sukla , Manoranjan Nayak, Jayashree Jena ,Himansu Sekhar Panda , Nilotpala Pradhan •,Prasanna Ku. Panda ,Santosh Ku. Mishra , Biswaranjan Das , Chandragiri Sarika , B.V S K.Rao , R. B. N.Prasad , B.K.Mishra In book: Environmental Technology, Publisher: Daya Publishing House,New Delhi, Editors: D.R.Khanna, A.K.Chopra, Gagan Matta, R.Bhutiani &Vivek Singh, pp.79-91,January 2013 ISBN 10: 817035823X / ISBN 13: 9788170358237

ABSTRACT: High energy prices, rising energy imports and greater recognition of environmental consequences of fossil fuels that becomes unsustainable have driven a spurring demand to look for sustainable, greener fuels that are economically competitive with environmental benefits. As an emphasis switched in production of natural oil for biodiesel, microalgae becomes most potential candidate for the research due to high oil content. Several researchers have advocated for large-scale microalgal cultivation as alternate raw material source for biodiesel production. In order to fully exploit this potential in a cost effective manner, the major challenges to be addressed are to increase the growth rate and improve the .lipid content of microalgal strains in large scale operation. The study of a potential brackish water microalga Scenedesmus sp. has been carried out in outdoor raceway pond for biodiesel production. The designed raceway pond is a closed circular loop made up of concrete and consists of agitation system (paddle wheels), CO2 sparging system (CO2 diffuser) and flow mixing system (Baffles). Cultivation was done in batch mode for 18 days. Every six day interval the microalgal culture was analyzed for growth, total lipid and fatty acid composition. Effect of agitation time on biomass growth was checked .The result shows significant increase in lipid accumulation from logarithmic phase to stationary phase i.e. from 7 % to 23% and the biomass yield was found to be 0.68 g/L on 18th day of cultivation time. Scenedesmus sp. grows fast, contains about 23% lipid with high percentage of unsaturated fatty acids and yield good biomass under optimal conditions making it favorable for biodiesel production. Further it was found that agitation in the raceway pond has significant effect on biomass growth. Increase in agitation efficiency, increases the biomass yield.

2.Microalgae: Cultivation and Application

V.Aishvarya ,J. Jena , M.Pradhan ,P.K.Panda ,L.B.Sukla ,Environmental Microbial Biotechnology, Edited by Sukla, L.B., Pradhan, N, PandaS, Mishra B.K. (Eds, 08/2015; Springer., ISBN: 978-3-319-19017-4 pp 289-311

3. Enhanced inorganic carbon uptake by Chlorella sp. IMMTCC-2 under autotrophic conditions for lipid production and CO2 sequestration

V. Aishvarya ,N. Pradhan , R. R. Nayak , L. B. Sukla , B. K. Mishra ,Journal of Applied Phycology 12/2012; 24(6). pp 1455-1463

ABSTRACT: To achieve sustainable production of biofuel from microalgae, a well-optimized and sustained biomass production is prerequisite. The major factor determining the higher productivity of algae is the availability and uptake of CO2 for biomass growth. In this study, an improved CO2 sequestration method leading to improved biomass yields has been investigated. The ability of OH− ions in fixing dissolved CO2 in form of HCO 3 − in algal growth medium was studied using a *Chlorella* sp. and scaled-up in a photobioreactor. It was observed that a critical concentration of 0.005 M OH− is required for HCO 3 − formation and utilization by algae. HCO 3 − uptake was enhanced by 70.8% (in presence of 0.01 M NaOH) with a sixfold increase in growth rate compared with only CO2 system. In mineral carbon systems such as NaHCO3 and Na2CO3, increase in HCO 3 − uptake was enhanced by 65.4% and 63.4%, respectively. The maximum rate of CO2 fixation of 6.6 mg L−1 h−1 was obtained with 0.01 M NaOH which was 1.5 times compared with mineral carbon sources. The biomass from scale-up experiment contained 16.3% lipid (by weight) of which 75% is unsaturated fatty acids (in total lipids). This supports the idea that fixing the dissolved CO2 in the form of bicarbonate using alkali helps in increased biomass productivity rather than CO2 itself, forms a precursor for biodiesel, and increases CO2 sequestration in a cyclic process.

4. Homology modeling and docking studies of FabH (β-ketoacyl-ACP synthase III) enzyme involved in type II fatty acid biosynthesis of Chlorella variabilis: A potential algal feedstock for biofuel production,

Namrata Misra ,Mahesh Chandra Patra , Prasanna Kumar Panda, Lala Bihari Sukla , Barada Kanta Mishra , Journal of biomolecular Structure & Dynamics 07/2012; 31(3). pp 241-57.

ABSTRACT: The concept of using microalgae as an alternative renewable source of biofuel has gained much importance in recent years. However, its commercial feasibility is still an area of concern for researchers. Unraveling the fatty acid metabolic pathway and understanding structural features of various key enzymes regulating the process will provide valuable insights to target microalgae for augmented oil content. FabH (β-ketoacyl-acyl carrier protein synthase; KAS III) is a condensing enzyme catalyzing the initial elongation step of type II fatty acid biosynthetic process and acyl carrier protein (ACP) facilitates the shuttling of the fatty acyl intermediates to the active site of the respective enzymes in the pathway. In the present study, a reliable three-dimensional structure of FabH from Chlorella variabilis, an oleaginous green microalga was modeled and subsequently the key residues involved in substrate binding were determined by employing protein-protein docking and molecular dynamics (MD) simulation protocols. The FabH-ACP complex having the lowest docking energy score showed the binding of ACP to the electropositive FabH surface with strong hydrogen bond interactions. The MD simulation results indicated that the substrate-complexed FabH adopted a more stable conformation than the free enzyme. Further, the FabH structure retained its stability throughout the simulation although noticeable displacements were observed in the loop regions. Molecular simulation studies suggested the importance of crucial hydrogen bonding of the conserved Arg(91) of FabH with Glu(53) and Asp(56) of ACP for exhibiting high affinity between the enzyme and substrate. The molecular modeling results are consistent with available experimental results on the flexibility of FabH and the present study provides first in silico insights into the structural and dynamical aspect of catalytic mechanism of FabH, which could be used for further site-specific mutagenic experiments to develop engineered high oil-yielding microalgal strains for biofuel production.

5.Phyco diversity assessment of Bahuda river mouth areas of east coast of Odisha, India

S. Bhakta , S.K. Das , M. Nayak , J. Jena , P.K. Panda , L.B. Sukla ,Recent Research in Science and Technology 2011, 2(4): pp 80-89

ABSTRACT: A total of 31 algal samples were collected from 5 sampling sites of various water bodies of Bahuda river mouth areas of Orissa during a collection trip in the month of January 2010. Altogether 36 algal taxa were reported belonging to Cyanobacteria/Cyanoprokaryota, Chlorophyta, Euglenozoa and Bacillariophyta. The species distribution indicates the dominance of green algae followed diatoms and blue green algae. The occurrence of species with respect to trophic status of these water bodies indicate that ditch is more eutrophicated in comparison to mesotrophic pond and oligotrophic river. Keywords: Phyco-diversity, Bahuda River, Odisha. http://scienceflora.org/journals/index.php/rrst/article/viewFile/668/654

6.Survey and Documentation of Brackish Water Algal Diversity from East Coast Region of Odisha, India

Himansu Sekhar Panda , Manoranjan Nayak ,Biswaranjan Das ,Bikram Kumar Parida ,Jayashree Jena ,Sukumar Bhakta ,Sandeep Panda , Prasanna Kumar Panda , Lala Bihari Sukla World Environment 2011; 1(1) pp 20-23

ABSTRACT: A total of 150 algal samples were collected from 14 sampling sites of various fresh water and brackish water habitats of east coast region of Odisha, India during the period 2009-2011. About 41 algal strains were isolated and cultured into their pure forms. Out of the collected strains 5 taxa of Bacillariophyta, 12 taxa of Cyanobacteria/ Cyanoprokaryota and 24 taxa of Chlorophyta have been identified using relevant monographs and are being screend to evaluate their potential for biofuel production.

7. Screening of Fresh Water Microalgae from Eastern Region of India for Sustainable Biodiesel Production

Manoranjan Nayak , Jayashree Jena , Sukumar Bhakta , Swagat S. Rath , Chandragiri Sarika ,Bhamidipati Venkata Surya Koppeswara Rao ,Nilotpala Pradhan , Manikkannan Thirunavoukkarasu ,Santosh Kumar Mishra , Prasanna Kumar Panda , Rachapudi Badari Narayana Prasad , Lala Behari Sukla Barada Kanta Mishra ,International Journal of Green Energy Volume 8, Issue 6, 2011 pages 669-683

ABSTRACT: Study of six different freshwater microalgae, collected from Odisha, eastern region of India, has been carried out to find out their potential for biodiesel production. The growth, total lipid, and fatty acid composition of six microalgal strains were determined. Chlorella sp. IMMTCC-2, which exhibited high lipid content with considerable amount of unsaturated fatty acids, was selected for culture in a self-designed photobioreactor in order to study the scale-up possibilities. The result shows significant increase in lipid accumulation from logarithmic phase to stationary phase in the photobioreactor, i.e., from 12.4 to 28.3%. Analyses of the present results suggest that Chlorella sp. IMMTCC-2 is appropriate for biodiesel production.

Scientific Communications of L.B.Sukla on *Manganese leaching*

1. Molecular identification of indigenous manganese solubilising bacterial biodiversity from manganese mining deposits.

Shreya Ghosh,Sansuta Mohanty,Sanghamitra Nayak,Lala B. Sukla,Alok P. Das, Journal of Basic Microbiology , Volume 56, Issue 3 March 2016 Pages 254–262

ABSTRACT: Manganese (Mn) ranks twelfth among the most exuberant metal present in the earth's crust and finds its imperative application in the manufacturing steel, chemical, tannery, glass, and battery industries. Solubilisation of Mn can be performed by several bacterial strains which are useful in developing environmental friendly solutions for mining activities. The present investigation aims to isolate and characterize Mn solubilising bacteria from low grade ores from Sanindipur Manganese mine of Sundargh district in Odisha state of India. Four morphologically distinct bacterial strains showing visible growth on Mn supplemented plates were isolated. Mn solubilising ability of the bacterial strains was assessed by visualizing the lightening of the medium appearing around the growing colonies. Three isolates were gram negative and rod shaped while the remaining one was gram positive, coccobacilli. Molecular identification of the isolates was carried out by 16S rRNA sequencing and the bacterial isolates were taxonomically classified as *Bacillus anthrasis* MSB 2,*Acinetobacter* sp. MSB 5, *Lysinibacillus* sp. MSB 11, and *Bacillus* sp. MMR-1 using BLAST algorithm. The sequences were deposited in NCBI GenBank with the accession number KP635223, KP635224, KP635225 and JQ936966, respectively. Manganese solubilisation efficiency of 40, 96, 97.5 and 48.5% were achieved by MMR-1, MSB 2, MSB 5 and MSB 11 respectively. The efficiency of Mn solubilisation is suggested with the help of a pH variation study. The results are discussed in relation to the possible mechanisms involved in Manganese solubilisation efficiency of bacterial isolates.

2. Manganese biomining: A review

A.P. Das , L.B. Sukla , N. Pradhan , S. Nayak , Bioresour Technol. 2011 Aug;102(16):7381-7

ABSTRACT: Biomining comprises of processing and extraction of metal from their ores and concentrates using microbial techniques. Currently this is used by the mining industry to extract copper, uranium and gold from low grade ores but not for low grade manganese ore in industrial scale. The study of microbial genomes, metabolites and regulatory pathways provide novel insights to the metabolism of bioleaching microorganisms and their synergistic action during bioleaching operations. This will promote understanding of the universal regulatory responses that the biomining microbial community uses to adapt to their changing environment leading to high metal recovery. Possibility exists of findings ways to imitate the entire process during industrial manganese biomining endeavor. This paper reviews the current status of manganese biomining research operations around the world, identifies factors that drive the selection of biomining as a processing technology, describes challenges in exploiting these innovations, and concludes with a discussion of Mn biomining's future.

3. Microbial Recovery of Manganese Using Staphylococcus epidermidis

Alok Prasad Das, Lala Behari Sukla, Nilotpala Pradhan , International Journal of Nonferrous Metallurgy, 2012, 1, 9-12

ABSTRACT: Manganese minerals are widely distributed throughout the globe. The most important industrial uses of Mn are in the manufacture of steel, non-ferrous alloys, carbon-zinc batteries and some chemical reagents. Microbial recovery of manganese from low grade manganese ores using bioleaching was investigated in this paper. A bacterial strain, Staphy-lococcus epidermidis (MTCC-435) was collected from microbial type culture collection, IMTECH Chandigarh and used for the experiment. The experimental results for bioleaching with S. epidermidis showed that under pH 5.5, particle size −150 μm, pulp density 10%, temperature 35°C and agitation 200 rpm, about 80% of Mn was recovered within 20 days of incubation.

4. Reductive Acid Leaching of Low Grade Manganese Ores

Alok Prasad Das, Sarpras Swain, Shriyanka Panda, Nilotpala Pradhan, Lala Behari Sukla , Geomaterials, 2012, 2, 70-72

ABSTRACT: Manganese recoveries from low-grade ores using organic acids as reducing agents were investigated in the present work. The acid leaching potential of both oxalic acid and citric acid were estimated. Manganese leaching amount were meas-ured by using standard manganese curve and estimated by titration method. Effects of various acid concentrations on leaching efficiency were studied. The observed result suggested prominent manganese recovery of 66% by oxalic acid at 2 M concentration whereas citric acid had less effect on leaching showing leaching percentage upto 40% in 6 days. Acid leaching of manganese ore with both the acids gave a comparative data stating that oxalic acid leached better than citric acid.

5. Consequences of manganese compounds: a review

A.P. Das, S. Ghosh, S. Mohanty & L.B. Sukla, Toxicological & Environmental Chemistry,Volume 96, Issue 7, pages 981-997 11 Feb 2015

ABSTRACT: Manufacturing of manganese (Mn) compounds, their industrial applications as well as mining overburden, has generated a potential environmental pollutant. Occupational exposure to elevated levels of Mn occurs during mining, welding, smelting and other industrial anthropogenic sources. Chronic and acute exposure of this metal pollutant leads to adverse consequences and is clinically categorized by various symptoms of neurotoxicity including cognitive, psychiatric symptoms, Parkinson's disease, extra pyramidal signs, manganism, dystonia, and motor system dysfunction. The aim of this review is to summarize the possible mechanism underlying Mn compounds-mediated neurotoxicity leading to neurodegenerative diseases. Our review endeavours to examine recent advances in research on Mn-related environmental pollution, Mn-induced poisoning, molecular mechanisms underlying Mn-induced neurotoxicity with case studies as well as current approaches employed for treatment and prevention of Mn exposure.

6. FUNGAL LEACHING OF MANGANESE ORE

C. Acharya, R.N. Kar, L.B. Sukla and Vibhuti N. Misra, Trans. Indian Inst. Met.,Vol.57, No. 5, October 2004, pp. 501-508

ABSTRACT: Bioleaching is technologically feasible for extraction of manganese from low grade ores (containing manganese less than 35% by weight). The principle involves the non-enzymatic reduction of pyrolusite [Mn(IV) oxides] to +2 oxidation state by fungi with the production of metabolites such as oxalic acid and citric acid. In the present investigation, a fungal strain, Penicillium citrinum was isolated from top soil of Joda East manganese mine area, Tata Iron and Steel Company(TISCO), Orissa. Growth of the fungus was determined in terms of the final pH of the growth medium, biomass dry weight and total acid produced by the fungus. These data were used to evaluate the growth kinetics. Finally, it was used for bioleaching of low grade manganese ore. Effect of various parameters on in-situ leaching of manganese ore with P. citrinum such as (a) particle size (b) pulp density (c) sucrose concentration (d) inoculum size and (e) duration of leaching were studied. The maximum solubilisation of manganese (64.6%) was obtained with particle size of -45µm of the ore at pulp density of 2% (w/v), sucrose concentration 10% (w/v) and inoculum size of 10% (v/v) in a period of 30 days.

7. Application of statistical design in the leaching study of low-grade manganese ore using aqueous sulfur dioxide

Pradyumna K. Naik, L. B. Sukla & S. C. Das,Volume 37, Issue 6, 2002,pages 1375-1389, Separation Science and Technology

ABSTRACT: Sulfur dioxide leaching studies on low-grade manganese ore were carried out at room temperature and atmospheric pressure. The experiments carried out using −150 µm particles aimed at determining maximum extraction of manganese, which was found to be 97.5%. It was possible to extract 96.7% manganese at twice the stoichiometric quantity of SO2 required for dissolution of manganese. The effect of particle size, stoichiometric quantity of SO2 added, and duration of leaching were studied using 33 full factorial design. The data were analyzed

qualitatively as well as quantitatively. In addition to this, kinetic equations were tested to determine the rate-controlling step of the reaction.

8. Microbial extraction of manganese from low grade manganese ore

Celin Acharya, Rabi Narayan Kar, Lala Behari Sukla , ARTICLE in TRANSACTIONS- INDIAN INSTITUTE OF METALS 54(3) · JUNE 2001,PP- 99-103

ABSTRACT: A low grade manganese ore collected from Joda East Manganese mines of Orissa was subjected to leaching with an indigenous fungal culture, Penicillium citrinum, isolated from the top soil of the same mines. It was found that an extraction of 64.58% of manganese was obtained under the following conditions: particle size, 45 microns: pulp density 2% (w/v): sucrose conc. 10% (w/v): inoculum size 10%(v/v) and duration 30 days.

Scientific Communications of L.B.Sukla on Iron Ore

1.Microbial Beneficiation of Salem Iron Ore Using Penicillium Purpurogenum

M mishra, M pradhan, L.B. sukla and B.K. mishra Minerals and Materials Transaction B 42(1),13-19,2010

ABSTRACT: High alumina and silica content in the iron ore affects coke rate, reducibility, and productivity in a blast furnace. Iron ore is being beneficiated all around the world to meet the quality requirement of iron and steel industries. Choosing a beneficiation treatment depends on the nature of the gangue present and its association with the ore structure. The advanced physicochemical methods used for the beneficiation of iron ore are generally unfriendly to the environment. Biobeneficiation is considered to be ecofriendly, promising, and revolutionary solutions to these problems. A characterization study of Salem iron ore indicates that the major iron-bearing minerals are hematite, magnetite, and goethite. Samples on average contains (pct) Fe2O3-84.40, Fe (total)-59.02, Al2O3-7.18, and SiO2-7.53. *Penicillium purpurogenum* (MTCC 7356) was used for the experiment. It removed 35.22 pct alumina and 39.41 pct silica in 30 days in a shake flask at 10 pct pulp density, 308 K (35 °C), and 150 rpm. In a bioreactor experiment at 2 kg scale using the same organism, it removed 23.33 pct alumina and 30.54 pct silica in 30 days at 300 rpm agitation and 2 to 3 l/min aeration. Alumina and silica dissolution follow the shrinking core model for both shake flask and bioreactor experiments.

2.Beneficiation of iron ore slime using Aspergillus niger andBacillus circulan,

N. Pradhan , B. Das, C.S. Gahan, R.N. Kar, L.B. Sukla,Bioresource Technology ,Volume 97, Issue 15, October 2006, Pages 1876–1879

ABSTRACT: Studies were carried out on the removal of alumina from iron ore slime containing (%) Fe2O3 75.7, Al2O3 9.95, SiO2 6.1, Fe (total) 52.94 with the help of *Bacillus circulans* and*Aspergillus niger*. *B. circulans* and *A. niger* showed 39% and 38% alumina removal after six and 15 days of in situ leaching at 10% pulp density, respectively. Culture filtrate leaching with *A. niger* removed 20% alumina at 2% pulp density with 13 day old culture filtrate. *B. circulans* was more efficient than *A. niger* for selective removal of alumina. In case of *A. niger* in situ leaching rather than culture filtrate leaching was found to be more effective.

3.Microbial Beneficiation of Iron Ore Collected from Rungta Mine Areas Using Aspergillus fumigates

M. Pradhan , M. Mishra , C.C. Rath , L.B. Sukla ,JAM 1 (5) 2014 pp 266 - 273

ABSTRACT: In the current study the fungus *Aspergillus fumigatus* was used to beneficiate the iron ore sample collected from Rungta mines, Odisha. The iron samples used in the experiment contains 58.2 % Fe, 5.7 % alumina and 5.0 % silica. Shake flask studies were carried out in Bromofield medium at 35oC, pH-6.8 and 150 rpm for 30 days. At the above conditions the maximum removal of alumina and silica by *A. fumigatus* was 24.5 % and 27.3 % respectively with drop in pH 1.8 from intial pH 6.8. Various optimization parameters like variation in growth medium,variation in pulp density and variation in temperature were studied with fungus. In Bromofield medium *A. fumigatus* observed to remove 24.5 % alumina and 27.3 % at optimum temperature 35oC at 5 % pulp density. The results of the study indicated a potential relationship between Alumina and Silica removal and the organic acids production by this fungus. It is therefore concluded that there is a potential prospect in the use of metabolite from this type of fungus for biobeneficiation of iron ore minerals.

4.Bio-beneficiation of iron ore using heterotrophic microorganisms

Sitharashmi Sahu, Madhushree Kundu and Lala Behari sukla,J. Microbiol. Biotech. Res., 2015, 5 (2):54-60

ABSTRACT: The present studies were carried out to remove alumina and silica from iron ore as a part of the microbial process development for iron ore slime beneficiation using heterotrophic microorganisms. Iron ore containing percentage Fe2O376.61, Al2O36.01, SiO27.6, P2O5 0.9, TiO20.2 and Fe (total) 53 leached out

15%, 8 % and 17 % of alumina and 10.6 %, 5.3 % and 20 % silica with the help of bacteria Bacillus polymyxa, Bacillus sphericus and Pseudomonas putida respectively, at the end of 10 days of in-situ leaching at 5 % pulp density. Aspergillus fumigatus, Penicillium citrinum and Aspergillus flavus were the fungus used for in-situ leaching of 10 days at 5 % pulp density showed alumina removal of 7 %, 6 % and 17 %, and silica removal of 8 %, 4 %, and 16 %, respectively. Aspergillus flavus and Pseudomonas putida were most efficient among all the bacteria and fungus used; ensuring an iron beneficiation of about 3 % by the selective removal of alumina and silica at the end of 10 days. Bacillus sphericus and Penicillium citrinum leach out iron simultaneously with alumina and silica. Apart from this, growth characteristics of A.flavous and P.putida have been studied in which bacteria showed rapid growth rate as compared to fungus whereas fungus has given more biomass than bacteria.

Scientific Communications of L.B.Sukla on URANIUM

1.Microbial recovery of uranium using native fungal strains

A. Mishra, N. Pradhan , R.N. Kar, L.B. Sukla, B.K. Mishra Hydrometallurgy,Volume 95, Issues 1–2, January 2009, Pages 175–177

ABSTRACT: Native microorganisms were isolated from water samples collected from uranium mines of Jaduguda, Bhatin and Nawapahar of UCIL India. Ten fungal strains isolated in pure cultures were selected, identified and used in this study. The strains were used for in situ leaching of mainly oxide low grade uranium ore of Turamdih mine. The maximum recovery of 71%uranium was obtained with the strain Cladosporium oxysporum. The other two strains belonging to Aspergillus flavus and Curvularia clavata gave 59% and 50% of metal recovery respectively from the same ore.

2.Micro-Raman analysis and AFM imaging of Acidithiobacillus ferrooxidans biofilm grown on uranium ore

Nilotpala Pradhan, Siddhartha K. Pradhan, Bijan B. Nayak, Partha S. Mukherjee,Lala B. Sukla, Barada K. Mishra Research in Microbiology 159 (2008) 557e561

ABSTRACT: Acidithiobacillus ferrooxidans biofilm grown on uranium ore substrate was analyzed by a micro-Raman spectrometer and an atomic force microscope (AFM). The bacterium employed for this study, A. ferrooxidans BM1, was isolated from a uranium mine (Jaduguda, India). Micro- Raman analysis revealed the different constituents of molecular fragments present in microbial cells and in secreted extracellular polymeric substances (EPSs). AFM images clearly revealed bacterial cells surrounded by EPS. From Raman spectral data, the composition of EPS from A. ferrooxidans BM1 appeared to be similar to that of EPS secreted in a different Pseudomonas bacterium

3.Bioleaching of low-grade uranium ore using Acidithiobacillus ferrooxidans

S. Pal, D. Pradhan, T. Das,L. B. Sukla, and G. Roy Chaudhury,Indian J Microbiol. 2010 Mar; 50(1): 70–75

ABSTRACT: Bioleaching of uranium was carried out with Turamdih ore sample procured from Uranium Corporation of India Limited, Jaduguda. The bacterial strain that was used in the leaching experiments was isolated from the Jaduguda mine water sample. Efficiency of bioleaching was studied by varying parameters like pulp density and initial ferrous concentration as source of energy. It is observed that the efficiency of bioleaching was 49% at 10% pulp density (w/v) and initial pH 2.0. Addition of external has no effect on efficiency of bioleaching showing domination of direct leaching mechanism over indirect.

Scientific Communications of L.B.Sukla on Other Publications (plasma, Biosurfactant & Phospherus)

1. Low temperature oxygen plasma assisted surface modification of raw silk fibre and their characterizations

R. R. Nayak & L. B. Sukla & B. K. Mishra International Journal of Plastics Technology,June 2013, Volume 17, Issue 1, pp 1-9

ABSTRACT: Raw silk fibre was treated with low temperature oxygen plasma with an aim to improve its dyeability. The XRD study reveals that a fraction of the macromolecules on the surface and in the inner part of silk fibres are oxidized during plasma treatment. The overall crystallinity of the fibre surface is reduced and the short range order is increased. Plasma treated fibre showed gradual increase of peak intensity in the Raman spectrum, and the peak shifts to lower wave numbers. Change in the micro-structural properties was observed in the scanning electron microscope images but the mechanical property of silk fibre was found to be insignificant. Smooth and homogeneous coating of a natural dye extracted from the Indian mulberry (Morinda citrifolia) was observed in the case of plasma-etched silk fibre.

2. Inhibition of pathogenic bacterial biofilm by biosurfactant produced by Lysinibacillus fusiformis S9

Arun Kumar Pradhan, Nilotpala,Pradhan, Lala Behari Sukla, Prasanna,Kumar Panda & Barda Kanta Mishra, Bioprocess Biosyst Eng. 2014 Feb;37(2):139-49

ABSTRACT: A biosurfactant producing microbe isolated from a river bank was identified as Lysinibacillus fusiformis S9. It was identified with help of biochemical tests and 16S rRNA gene phylogenetic analysis. The biosurfactant S9BS produced was purified and characterized as glycolipid. The biosurfactant showed remarkable inhibition of biofilm formation by pathogenic bacteria like Escherichia coli and Streptococcus mutans. It was interesting to note that at concentration of 40 lg ml-1 the biosurfactant did not show any bactericidal activity but restricted the biofilm formation completely. L. fusiformis is reported for the first time to produce a glycolipid type of biosurfactant capable of inhibiting biofilm formation by pathogenic bacteria. The biosurfactant inhibited bacterial attachment and biofilm formation equally well on hydrophilic as well as hydrophobic surfaces like glass and catheter tubing. This property is significant in many biomedical applications where the molecule should help in preventing biofouling of surfaces without being toxic to biotic system.

3. Solubilization of inorganic phosphates by fungi isolated from agriculture soil

N Pradhan, and LB Sukla, African Journal of Biotechnology Vol. 5 (10), pp. 850-854, 16 May 2005

ABSTRACT: Most agricultural soils contain large reserves of phosphorus (P), a considerable part of which accumulates as a consequence of regular applications of P fertilizers. However, a greater part of soil phosphorus, approximately 95–99% is present in the form of insoluble phosphates and hence cannot be utilized by the plants. In the present study fungal strains isolated from agriculture soil, having potential to solubilize insoluble inorganic phosphates were characterized. Two fungal isolates were tested for their tricalcium phosphate (TCP) solubilization efficiency in both solid and liquid medium. Isolates were identified as Aspergillus sp. and Penicillium sp. depending upon their colony morphology and microscopic studies. Phosphate solubilization was related to pH decrease caused by growth of fungus in medium containing glucose as carbon source. Aspergillus sp. solubilized 480 _g/ml of phosphorus, while Penicillium sp. solubilized 275 _g/ml of phosphorus from 0.5% tricalcium phosphate after 4 and 3 days of growth respectively. Both the strains show diverse levels of phosphate solubilization activity in liquid broth culture in presence of various carbon and nitrogen sources. Drop in pH during growth was more prominent in absence of TCP in the liquid medium. This indicates that absence of soluble P in media induces the acid production. Phosphate solubilizing microorganisms convert insoluble phosphates into soluble forms generally through the process of acidification, chelation and exchange reactions. Thus such microorganisms may not only compensate for higher cost of manufacturing fertilizers in industry but also mobilizes the fertilizers added to soil.

4. Dephosphorization of LD slag by phosphorus solubilising bacteria

N.P. Marhual, N. Pradhan, N.C. Mohanta, L.B. Sukla, B.K. Mishra, International Biodeterioration & Biodegradation Volume 65, Issue 3, June 2011, Pages 404–409

ABSTRACT: Phosphorus is one of the major nutrients, and microbial solubilisation of insoluble mineral phosphate in soil is an important process in natural ecosystem and in agricultural soil. Many soil microorganisms display the ability to solubilize many insoluble inorganic phosphates. They are generally referred as phosphorus solubilising microorganisms (PSM). In this study an attempt was made to look into the phosphorus solubilisation efficiency of some commonly available soil bacteria and their possible application in bio-beneficiation of metallurgical waste like LD Slag. Linz eDonawitz (LD) slag is produced in large quantities (200 kg LD slag per ton of hot metal) and poses a substantial disposal problem in the iron and steel making industry. LD slag contains around 29% Ca, 21% Fe, and 5% Mg. Its phosphorus content is about 1.5e6%. Due to presence of high amount of Ca, it can be used as flux in blast furnace, but presence of high amount of phosphorus in the LD slag makes them unsuitable for industrial application. Removal of phosphorus with the help of phosphorus solubilising microorganisms may be a great advantage in biotechnological applications. Two gram positive bacteria belonging to genus Bacillus and two gram negative bacteria belonging to genus Pseudomonas were selected in this study. Phosphorus solubilisation efficiency was studied initially with tricalcium phosphate as model insoluble phosphate compound at different sugar concentration, NaCl concentration and at different initial pH of the medium. About 35% of 'P' could be solubilized from LD slag by Pseudomonas aeruginosa at 2% solid content.

5. Dissolution of heavy metals from electrostatic precipitator (ESP) dust of a coal based sponge iron plant by fungal leaching

Pradip K. Jena, C. S. K. Mishra, D. K. Behera, S. Mishra and L. B. Sukla, African Journal of Environmental Science and Technology Vol. 6(4), pp. 208-213, April 2012

ABSTRACT: Coal based sponge iron industries in India generate considerable quantity of solid waste, 40% of which is flue dust produced from the electrostatic precipitator (ESP) connected to rotary kiln. This paper reports the dissolution of Zn, Cu, Pb, Mn and Fe from the ESP dust using three fungal species, Aspergillus niger, Aspergillus fumigatus and Aspergillus flavus at 5 and 10% pulp densities over a period of 28 days. Highest metal leaching was achieved with A. niger followed by A. flavus. The least metal leaching was achieved with A. fumigatus. The pH of the medium declined consistently over the incubation period. Maximum leaching for Zn, Cu, Pb, Mn and Fe were 81, 76, 74, 72 and 52% respectively.

6. Population coverage analysis of T-Cell epitopes of Neisseria meningitidis serogroup B from Iron acquisition proteins for vaccine design.

Namrata Misra, Prasanna Kumar Panda, Kavita Shah, Lala Bihari Sukla,Priyanka Chaubey, Bioinformation. 2011;6(7):255-61

ABSTRACT: Although the concept of Reverse Vaccinology was first pioneered for sepsis and meningococcal meningitidis causing bacterium, Neisseria meningitides, no broadly effective vaccine against serogroup B meningococcal disease is yet available. In the present investigation, HLA distribution analysis was undertaken to select three most promiscuous T-cell epitopes out of ten computationally validated epitopes of Iron acquisition proteins from Neisseria MC58 by using the population coverage tool of Immune Epitope Database (IEDB). These epitopes have been determined on the basis of their binding ability with maximum number of HLA alleles along with highest population coverage rate values for all the geographical areas studied. The comparative population coverage analysis of moderately immunogenic and high immunogenic peptides suggests that the former may activate T-cell response in a fairly large proportion of people in most geographical areas, thus indicating their potential for development of epitope-based vaccine.

7. Synthesis and photo-physical properties of polymeric soft materials and its application in FRET based DNA sensor.

Rati Ranjan Nayak & N. Pradhan & L. B. Sukla & B. K. Mishra International Journal of Plastics Technology,December 2010, Volume 14, Supplement 1, pp 1-6

ABSTRACT: Water-soluble conjugated polyelectrolytes (CPs) an ideal advanced soft materials have attracted considerable attention as an optical platform in chemical and biological assays for nucleic acids, proteins, enzyme activities and physiological metal ions. From the viewpoint of detection sensitivity, CPs-based assays benefit from their light-harvesting properties via collective response of optical units along the polymer backbone. In the present investigation we have successfully synthesized a cationic conjugated polymer via Suzuki copolymerization and successive quaternization. In order to enhance its optical property for efficient biosensor materials, a polymer-surfactants micellar complex approach has been made. In water, the molar absorptivity and fluorescence quantum efficiency of cationic poly (fluorene-co-phenylene) (c-PFP) were substantially increased in the presence of nonionic surfactants. About 400% enhancement of the FRET signal was measured in c-PFP/ssDNA-Fl with Brij 30, relative to that without surfactants. The signal amplification was successfully modulated using different type of non-ionic surfactants which perturb the complexation, fine-structure of the complex (i.e., donor-acceptor separation) and the resulting energy transfer process.