

BIOREMEDIATION OF NICKEL CONTAMINATED SOIL USING BACTERIA

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ABSTRACT

Bioremediation is the use of living organisms (primarily microorganisms) for removal of a pollutant from the biosphere. It relies on biological processes to minimize an unwanted environment impact of the pollutants. The microorganisms in particular have the abilities to degrade, detoxify and even accumulate the harmful organic as well as inorganic compounds. Soil samples were collected from J P Cement Plant, Rewa from different places at a depth of 6 -10 Inches from 4 - 6 different spots. These soil samples were mixed properly and enriched for Nickel resistant clones by incubating 10g of slag in 90 ml of sterile water amended with 10 ml Luria Bertani (LB) medium and 20 µg/ml each of nickel sulphate at 37°C for 2h. Supernatants were plated at 10⁻² dilution by spread-plate method on LB agar medium. The plates were then incubated at 37°C. The colonies appeared after 3 days. Strains were preserved and phenotypic studies were carried out. The metal accumulation efficiency was measured by Atomic Absorption Spectroscopy (AAS). The soil samples collected are all alkaline in nature, the isolated bacteria are gram positive, rod shaped, aerobic, salt tolerant, endospore forming bacteria and according to this research sample with bacterial inoculation in them shown reduction in the Nickel levels as compared to the raw soil samples.

KEYWORDS: Bioremediation, Heavy metals, Nickel, Soil, Bacteria.

1. INTRODUCTION

Heavy metals have a major problem to human health and environmental issues due to the high incidence as a contaminant, low solubility in biota and classification of various heavy metals as carcinogens and mutagens.^[1] Heavy metals can produce harmful effects on human health when they are taken up in amounts that cannot be processed by the organism. In addition, these metals cannot be degraded to harmless products and hence persist in the environment indefinitely.^[2] Contamination of heavy metals in the environment is a major global concern, because of toxicity and threat to the human life and ecosystem.^[3] The levels of metals in all environments, including air, water and soil are increasing in some cases to toxic levels, with contributions from wide variety of industrial and domestic sources.^[4] Metal contaminated environments pose serious threat to health and ecosystems. Metals like arsenic, cadmium, nickel, mercury etc cause conditions including hypophosphatemia, heart disease and liver damage, cancer and neurological and cardiovascular diseases, central nervous system damage and sensory disturbances.^[5] Bay incident of Japan is an example of heavy metal poisoning which occurred due to

consumption of fishes and shellfishes contaminated with methylmercury in their body.^[6] The ecological effects of toxic metals and their biological magnification through the food chain have prompted a demand for decontamination of heavy metals.^[7] Nickel released into the environment by a large number of processes such as electroplating, leather tan-ning, wood preservation, pulp processing, steel manufacturing, etc.^[8] This metal is of major concern because of their larger usages in developing countries and their non degradability nature.^[9] Nickel uptake will boost when people eat large quantities of vegetables from polluted soils. Smokers have a higher nickel uptake through their lungs. An uptake of too large quantities of nickel cause higher chances of development of cancer, Sickness and dizziness after exposure to nickel gas, lung embolism, respiratory failure, birth defects, asthma and chronic bronchitis, allergic reactions such as skin rashes mainly from jewelry, heart disorders.^[10] Several methods have been designed for the treatment and removal of heavy metals in contaminated site. Physico-chemical methods have been used, such as electrochemical treatment, ion exchange, precipitation, reverse osmosis, evaporation, and sorption.^[11,12] Ex situ remediation techniques involve removing the soil from the subsurface to treat it. Insitu

remediation techniques involve leaving the soil in its original place and bringing the biological mechanisms to the soil. But these methods have disadvantages, including economically expensive, incomplete metal removal, requirements higher reagent energy, and generation of toxic sludge.^[13,14] Because of toxicity and the ubiquity of the metals in environment, microbes have developed unique and sometimes bizarre ways of dealing with unwanted metals. Some microorganisms have mechanisms to sequester and immobilize metals, whereas others actually enhance metal solubility in the environment. Sometimes they oxidize or reduce them to a non-toxic or relatively less toxic forms.^[15] Bioremediation is a sustainable strategy that utilizes the metabolic potential of microorganisms and plants to clean-up contaminated environments.^[16]

It achieves contaminant decomposition or immobilization by exploiting the existing metabolic potential of microorganisms with novel catabolic functions derived from selection or by introduction of genes encoding such functions.^[17] The most essential parameters required for bioremediation are the nature of pollutants, soil structure, temperature, pH, moisture content, hydrogeology, the nutritional state, redox-potential, and microbial diversity of the site. In bioremediation processes, microorganisms use the contaminants as nutrient or energy sources.^[18] Bioremediation is a cost effective eco-friendly means of healing nature with nature. This technology may be applied in the removal of xenobiotic compounds from agrochemical and petrochemical industries, oil spills, heavy metals in sewage, sludge and marine sediments etc.^[19]

2. MATERIALS AND METHODS

2.1 Collection of soil samples

Soil samples were collected from J P Cement Plant, Rewa from different places at a depth of 6 -10 Inches from 4-6 different spots.

2.2 Physicochemical characteristics

Different physico-chemical characteristics of the leachate such as pH, Dissolved Oxygen (DO), alkalinity and total water content were determined for both freshly produced slag and old slag deposited considerably since long period of time. Methodologies followed were according to American Public Health Association (APHA).^[20]

2.3 Strains isolation

The samples were mixed properly and enriched for each Nickel resistant clones by incubating 10 g of soil in 90 ml of sterile water amended with 10 ml LB (Luria Bertani) medium and 20 µg/ml of nickel sulphate at 37 °C for 2 hour. Supernatants were plated by spread-plate method at 10⁻² dilution on LB agar medium containing 20 µg/ml of Nickel Sulphate [Ni(SO₄)], then the plates were incubated at 37 °C. After 3 days of incubation the colonies were appeared which were further screened at higher concentrations (20-800 µg/ml) of each heavy

metal. Finally strains were selected as nickel resistant isolates for further studies.

2.4 Maintenance and preservation of cultures

Strains were preserved in the refrigerator in stabcultures made of LB medium and NA medium both for short time preservation. The media were all the time supplemented with 20 µg/ml of heavy metal and for long time preservation glycerol stocks were made for storage in – 70 °C for longer period of time. For this overnight grown liquid culture were taken in cryo-vials and added with 15% glycerol after this the vials were transferred to – 70 °C deep freezer.

2.5 Phenotypic studies and Determination of Maximum Tolerance Limit (MTL)

Phenotypic studies such as colony morphology, Gram staining, endospore staining, motility, biochemical tests, acid production tests etc. were carried out as per standard methods of Benson, 1990 in our laboratory.^[21] MTL was determined by growing cells both in LB broth and LB agar media which had been amended with increasing concentrations of respective heavy metal. Heavy metal (Ni) stock were prepared in sterile distilled water and was added at the time of inoculation of specific bacterial isolates in inoculating chamber.

2.6 Heavy metal accumulation efficiency measurement

The heavy metal accumulation efficiency was measured by Atomic Absorption Spectroscopy (AAS). For this 500 mg cell pellets obtained at different time intervals were suspended in 20 ml water added with 5% conc. HNO₃ and 0.5% conc. HCl. The cell suspensions were then digested in Anton Paar MDS according to User 001H of Perkin Elmer Application Note (Instruction Manual, Perkin Elmer AAnalyst 700). Following digestion, the cell extracts were analysed in AAS.

3. RESULTS AND DISCUSSION

The physico-chemical characteristics indicate that the place is unsuitable for the growth of plant mainly because of high pH. The older slag is more alkaline than the slag deposited recently. The dissolved oxygen of the older slag is also considerably higher than the fresh slag. The Nickel resistant strain is a gram positive, rod shaped, aerobic, salt tolerant, endospore forming bacteria. To study the maximum tolerance limit (MTL), cells were grown in LB broth with increasing concentrations of heavy metal and growth was observed, the maximum tolerance limit of Nickel resistant bacteria was 600µg/ml. The concentrations of heavy metal were determined using Atomic Absorption Spectroscopy (AAS) as described in materials and methods. The concentrations were determined at 12 hrs, 18 hrs, 24 hrs and 48 hrs of growth. it can be seen that the accumulation of heavy metal (Nickel) increases gradually in log phase and they show maximum level of accumulation at late log phase to stationary phase (i.e. at 18-20 hrs), however, the concentrations of Nickel decrease when the cells enter

stationary to death phase. The maximum accumulation efficiencies of Nickel resistant strain as determined by

atomic absorption spectroscopy were 0.132 mg/g (Figure 1).

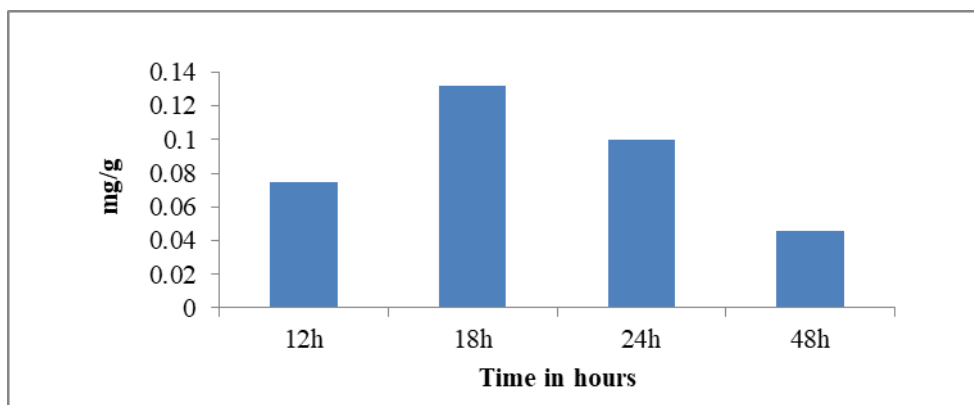


Figure 1: Heavy metal accumulation efficiencies at different time intervals.

The principal purpose of this study was to isolate and characterize heavy metal resistant bacteria from slag with respect to their heavy metal accumulation efficiencies. As has been discussed earlier that after a few rounds of screening at consecutively increasing concentrations of Nickel, bacterial isolates were screened and selected for further studies. The alkaliphilic nature and salt tolerant abilities of the strains are significant with respect to their application in metal contaminated, salinated, alkaline soil for bioremediation. Moreover, the slag, the natural habitat from which these bacteria were isolated also had a pH of 9.8. The increased metal tolerance in relation to pH has been reported in *Aspergillus* sp.^[22] The Nickel accumulation efficiency of the strain as determined by atomic absorption spectroscopy was found to be optimum at 18 hours after inoculation when the population reached almost the maximum density. The accumulation efficiency then decreased considerably indicating it to be an active uptake system requiring energy for transport across the membrane.^[23] It has been shown that microbes have the capability to reduce heavy metals, but whether they reduce it for detoxification or for growth is a matter of concern. In a sample of agricultural soil, arsenate reduction was not coupled to growth,^[24] rather it could be linked to detoxification. However, in the JMM-4 strain of *Bacillus* sp., a close relative of *Bacillus arsenicoselenatis* isolated from arsenic contaminated mud in Australia had been capable of oxidizing lactate to acetate while reducing arsenate to arsenite.^[25] Regarding Nickel resistance there are reports that level of resistance for Nickel is also directly related with the biomass which is in accordance with our study.^[26]

4. CONCLUSION

Conclusively, the bacterial isolates isolated from the slag disposal site of JP Cement factory Rewa, MP, India have been characterized in the present study with respect to their heavy metal acquisition and resistance and according to this research sample with bacterial inoculation in them shown reduction in the Nickel levels as compared to the raw soil samples. Thus it has been

concluded that bioremediation is a potential method for solving the problem of heavy metal pollution.

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