Role of Yeasts in Bioremediation of dumpsites

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Abstract

Bioremediation is a technology which deals with detoxification of the contaminants in a natural and cost effective manner using biological agents. Yeasts have been known to be one of such agents. They transform or degrade the contaminants into non- hazardous or less toxic substances. Nearly all human activities generate waste and its unscientific handling making the public prone to health hazards, directly or indirectly due to adversely affecting the environment. In most of the cities the municipal waste is disposed out side the city at the dumping sites. The contaminants not only pollute the air around but also they leach out, percolate and contaminate the soil and underground water. thus rendering it unfit for human use. There is a need to treat this waste scientifically so as to minimise the threat. The bioremediation technique using yeasts provides a means of converting this hazardous waste into non- hazardous substances in a cost effective way.

Key words: Dumpsites, contaminants, bioremediation, yeasts, Heavy metals.

Introduction

Generation of waste is an inevitable component of the industrial and community activity. It is reported that unscientific dumping of municipal wastes is very common disposal method in many Indian cities which cause adverse impacts to the environment. Nearly all human activities generate waste, and the way in which this is handled, stored, collected and disposed of, can pose risks to the environment and to public health (Zhu et al., 2017) Several fluxes of waste and cover materials from different sources end up at these dumpsites and due to the heterogeneity and complexity of wastes, these dumpsites contain a variety of contaminants which can pollute the soil of the area. The physico-chemical properties of the degraded soils at these sites are one of the important factor playing roles in vegetation development. Different Sources such as electronic goods, painting waste, used batteries, etc., when dumped with municipal solid wastes raise the heavy metals in dumpsites and dumping devoid of the separation of hazardous waste can further elevate noxious environmental effects. Environmental impact of land filling of MSW can usually result from the run-off of the toxic compounds into surface water and groundwater which eventually lead to water pollution as a result of percolation of leachate (Rajkumar et al., 2010). The occurrence of various heavy metals such as Mn, As, Cr, Cd, Ni, Zn, Co, Cu, and Fe in MSW dumpsites was reported by many workers (Azeez et al, 2011, Gupta el 2013, Solomon, 2019). Since these contaminants affect the environmental qualities in and around such open dumpsites, monitoring of soil qualities especially heavy metal content in dumpsite becomes necessary which can facilitate to recommend suitable remedial measures (Tripathi and Misra, 2012). Available literature reveals that the major cations and anions present around any dumpsite were sodium, calcium, chloride and sulphate respectively and were found to be beyond the prescribed limit. The moderately high concentrations of sodium, chloride and potassium in soil and groundwater, likely indicate that groundwater quality is being significantly affected by percolation of leachate (Ramaiah and Krishnaiah, 2014).

Generation of waste is an inevitable component of the industrial and community activity. Gupta et al., (2013) in their study considered a few industrial area dumpsites for detailed investigation evaluation of the impact of pollution potential on soil and subsequent ground water resources They found that Municipal solid waste management is one of the major environmental problems of Indian cities and in the case study of Lucknow, the main metropolis in Northern India, also succumbs to a major problem of municipal solid waste and its management (Gupta et al., 2013)

There are some biggest and oldest dumpsites with huge quantity of broad spectrum of wastes. Many industries of all nature are located in and around the dump sites. As per the information available, many dumpsites are more than 20 years old and dumpsite spread area is not uniform, with depth of waste materials dumped was about 10-15 feet. It was observed that various kinds of industrial wastes like Oil waste, glass wool, chemical wastes, pharmaceutical wastes, metallic waste, ceramic wastes plastic wastes, stone dust, electronic wastes etc, were dumped in an unscientific manner. Most of the industries discharge solid, liquid and hazardous wastes with or without any pre-treatment. The hazardous waste so generated is presently temporarily stored or stockpiled within industrial premises. The emissions from unscientific disposal of solid/liquid and hazardous waste from industries contain most dangerous heavy metals, acids, oil emissions, toxic wastes or infectious waste which can spread dreaded diseases to man and damage to the environment. The study area has highly undulating topography and predominantly consisting of granites and gneisses which are crisscrossed by pegmatite and are highly jointed. The climate in the study area is generally hot and humid and is characterized with seasonal variations of the year.

The presence of heavy metals in soil sample indicated that there is appreciable contamination of the soil by leachate migration from an open dumping site. It looks evident that these pollutants species will continuously migrate and attenuate through the soil strata and after certain period of time they might contaminate the ground- water.

It has been assessed that bad solid waste disposal situation in cities and there is a need to identify prospect for improvement focusing on remediation of dump sites and sanitary land filled. Problem with indiscriminate dumping increasing difficulty with acquiring suitable disposal sites (Gupta et al., 2013)

INDISCRIMINATE DUMPING CONTAMINATE THE SOIL & WATER QUALITY

Tripathi and Mishra, (2012) found that there are very few reports on the status of waste management in Allahabad city where emphasis is laid down on the characterization and management condition only. The study area is lacking in the information of soil qualities in and around such landfill areas. Therefore this study attempted to quantify the changes in the properties of soil under municipal waste dumping by comparing them with the properties of soils of adjoining areas under normal uses. Keeping these specifics in mind, the present study was undertaken to compare the influences of municipal waste dumping on selected soil physico-chemical properties and heavy metal levels. A significant importance of this work will be in providing baseline information for further soil quality monitoring studies and to understand their potential uses in making various soil amendments in future studies.

The concentration of heavy metals was studied in the soil samples collected around the municipal solid waste open dumpsite, Ariyamangalam, Tiruchirappalli, Tamil nadu to understand the heavy metal contamination due to leachate migration from an open dumping site. The dump site receives approximately 400–470 tonnes of municipal solid waste. Solid waste characterization was carried out for the fresh and old municipal solid waste to know the basic composition of solid waste which is dumped in the dumping site. The heavy metal concentration in the municipal solid waste fine fraction and soil samples were analyzed. The heavy metal concentration in the collected soil sample was found in the following order: Mn < Pb < Cu < Cd. The presence of heavy metals in soil sample indicates that there is appreciable contamination of the soil by leachate migration from an open dumping site. However, these pollutants species will continuously migrated and attenuated through the soil strata and after certain period of time they might contaminate the ground-water system if there is no action to be taken to prevent this phenomenon. (Kanmani and Gandhimathi, 2013)

Heavy metal pollution is nowadays one of the most important environmental concerns. Anthropogenic activities like metalliferous mining and smelting, agriculture, waste disposal or industry discharge a variety of metals such as Ag, As, Au, Cd, Co, Cr, Cu, Hg, Ni, Pb, Pd, Pt, Rd, Sn, Th, U and Zn, which can produce harmful effects on human health when they are taken up in amounts that cannot be processed by the organism.

Victoria and Lajide, 2015 **r**eported that heavy metals can be harmful to the biota and human beings when present above certain tolerable levels in the ecosystem. This lead to the study of the accumulation, contamination and pollution of these metals in soils of two refuse dumpsites within and outskirts of Akure Township, capital city of Ondo State, Nigeria. The dumpsites are places where wastes such as industrial wastes, automobile wastes, municipal wastes, agricultural wastes, etc were dumped. At each site, soil samples were collected randomly from nine different points of about 1m part at depth of about 0-30cm and analyzed for heavy metals and pH. The metals analyzed include Zn, Fe, Co, Cu, Ni, As, Ba, Pb, Cr and Cd using Atomic Absorption Spectrophotometer (AAS) with HF/Aqua regia wet digestion method. The pH of the soils ranged between 7.49 and 8.66. The results revealed heavy metal presence and implicated wastes as the major sources of the heavy metals in the soils of the dumpsites. All the metals were detected in all the soil samples except Arsenic that was not detected in three points at site A. Fe had the highest concentrations, while Ni had the least concentration in both sites. The trend in concentration was Fe > Zn >Pb> Cu> Cd> Co> Cr >As>Ba>Ni in site A, While the trend in concentration was Fe> Cr> Zn> Cu >Pb>Cd> Co> As > Ba> Ni in site B. The mean metal concentrations were compared with Department of Petroleum Resources (DPR) Standard values for soils in Nigeria, all the metals except Cr and Cu are below the DPR target values while Cd and Arsenic are above the DPR intervention values for the two sites, and this calls for immediate remediation.

Mshelia et al., (2014) Soil sample assessment was conducted on five dumpsites located within Maiduguri Metropolis, Nigeria. These includes; Bulunkutu (BLKT), Railway (RLWY), State Low-cost (STLC), Infectious Disease Hospital (IDH) and Nigerian National Petroleum Corporation (NNPC) depot. Soil samples were collected at each site while the controls were collected 10 m away from each site. Heavy metals were analyzed using AAS Perkin Elmer Model. These include; Cobalt, Arsenic, Cadmium, Chromium, Copper, Iron, Manganese, Nickel, Lead and Zinc. Physicochemical parameters such as pH, Electrical conductivity (EC) and Temperature were also determined. The mean value and Standard Deviation (SD) of the results were calculated. Most of the dumpsite soils were found to be slightly alkaline with pH range of $8.09 \pm 0.04 – 8.32 \pm 0.03$ recorded for IDH and Bulunkutu. Pearson correlation results showed strong and significant relationship between concentrations of some heavy metals and physicochemical parameters at α=0.05 levels. Bulunkutu soil sample pH correlates strongly and significantly with the concentrations of Cd and Cu respectively. Geoaccumulation index showed moderate to strong levels of contamination, Railway and NNPC Depot dumpsites showed no trace of contamination while Bulunkutu dumpsite indicated strong Co and P contamination.

BIOREMEDIATION OF DUMPSITES

Physical and chemical methods have been proposed for the removal of these pollutants, (Jain et al., 2014). Conventional methods to remediate heavy metals contaminated site are excavation and solidification/ stabilization, these technologies are suitable to control contamination but not permanently remove heavy metals. Nevertheless, they have some disadvantages, among them cost-effectiveness limitations, generation of hazardous by-products or inefficiency. Biological methods solve these drawbacks since they are easy to operate, do not produce secondary pollution. Heavy metals having relatively high density are toxic at low concentration. Microorganisms and plants are usually used for the removal of heavy metals.

BIOREMEDIATION

Process of involvement of microorganisms to reduce pollutant concentration is known as bioremediation which is a natural process and its importance of biodiversity (above or below the ground) is increasingly considered for clean-up of metal contaminated and polluted ecosystem. All the metals are toxic, but some of these are useful in low concentration. These metal toxicity cause serious morbidity and mortality. The bioavailability can be improved by addition of organic nutrients to the soil such as manure, compost, biosolids, which condition the soil and increases the fertility of soil. Bioremediation can be carried out both in aerobic and anaerobic condition. But aerobic conditions prove to be faster compared to that of anaerobic condition.

Bioremediation technologies.

In order to choose an effective bioremediation technology, there are various factors that we need to consider. The nature of contaminant, the size and characteristics of the contaminated surface, the final goal and the process and the costs. Since we cannot apply bioremediation as a singular technology, the geological, hydrological and microbiological aspect of the area to be remediated becomes a limiting factors.

The bioremediation technologies may be applied ex situ i.e. the polluted soil is taken away from the site and is subject to various treatments in bioreactors, where as in situ- involves treatment of the contaminated soil at the site itself by augmenting the metabolic activities of the indigenous microbial communities by supplementing some of the limiting growth factors e.g. oxygen, Phospohorus and Nitrogen.

Currently the most commonly used bioremediation strategies are based on the following principles:

Bioaugmentation- mostly used for soil bioremediation by adding the micro-organisms or specific enzymes with degrading effects on the polluted substrate.

Bioventing - In bioventing, the air is ventilated through soil which supplies enough oxygen to increase the growth of indigenous or exogenous micro-organism.

In situ Biodegradation- At the site of contamination, the aqueous solution containing nutrients and oxygen are circulated through the soil, improving the growth rate of micro-organisms.

Bioreactors are used for soil as well as water remediation, by creating mixing conditions which will increase the bioremediation of soil bound or water soluble contaminants.

Biofilters- They are used for volatile organic compounds which are removes by air circulation through compost or soil containing micro organisms with xenodegrading abilities.

Landfarming- Oil spills effects are reduced by spreading the contaminated soil over a prepared bed, and the microbial biodegradative activity is stimulated through aeration.

Composting- The polluted soil is mixed with non-toxic organic compounds required for the development of rich microbial population which brings about the bioremediation.

ROLE OF YEASTS IN BIOREMEDIATION

Bioremediation has many advantages compared to the conventional decontamination techniques, such as maintaining the ecological equilibrium, the contaminants are eliminated through microbial metabolic processes, biological systems transport costs are relatively low and use less energy. Various decontamination techniques have their side effects and more pollution of different kind.

The isolation of heavy metal resistant microorganisms and the understanding of the mechanisms they use in order to remove this kind of pollutants may contribute to the development of improved bioremediation processes. Jain et al., (2014) aimed to study the ability of bioremediation process with microbial isolates and amendments to remove heavy metals from polluted soil residue.

Staphylococcus, Bacillus, Pseudomonas, Citrobacteria, Klebsiella, Rhodococcus, Rhodotorula and Pichia are the commonly used microorganisms in bioremediation processes which include bio-augmentation wherein microbes and nutrients are added to supplement the intrinsic microbes of the site for bio-stimulation or sometimes nutrients and enzymes are added to supplement the intrinsic microbes of the site and mentioned by Abatenh E, Gizaw B, Tsegaye Z, et al.(2017). These metal contaminants pose adverse health effects on those who live near the polluted sites. It has already been established that heavy metals and heavy metal toxicity possess serious threat to our environment leading to severe health hazards which may even claim our lives. Thus considering this acute environmental problem and environmental sustainability, our research interest has prompted us to intensify our study on bioremediation of heavy metals (lead and chromium) by using heavy metal resistant microorganisms. Keeping this view in mind, Chatterjee, S. (2015) isolated and identified the heavy metal tolerant microorganisms and a heavy metal tolerant/resistant yeast strain (*Rhodotorula mucilaginosa*) was isolated from effluent of Chittaranjan Locomotive Workshop. Edgardo Rubén Donati et al. 2019. has mentioned the use of yeast in the bioremediation processes due to their being extremophiles.

ROLE OF PLASMA MEMBRANE BOUND ENZYMES IN THE PROCESS OF BIOREMEDIATION

Balaji et al., 2014 reported about the fungal strains capable of secreting extracellular enzymes by utilizing hydrocarbons present in the contaminated soil. Fungal strains were enriched from petroleum hydrocarbons contaminated soil samples collected from Chennai city, India. The potential fungi were isolated and screened for their enzyme secretion such as lipase, laccase, peroxidase and protease and also evaluated fungal enzyme mediated PAHs degradation. Total, 21 potential PAHs degrading fungi were isolated from PAHs contaminated soil, which belongs to 9 genera such as *Aspergillus, Curvularia, Drechslera, Fusarium, Lasiodiplodia, Mucor, Penicillium, Rhizopus, Trichoderma*, and two oilseed-associated fungal genera such as *Colletotrichum* and *Lasiodiplodia were* used to test their efficacy in degradation of PAHs in polluted soil. Maximum lipase production was obtained with *P. chrysogenum, M.racemosus* and *L.theobromae* VBE1 under optimized cultural condition, which utilized PAHs in contaminated soil as sole carbon source. Fungal strains, *P. chrysogenum, M. racemosus* and *L. theobromae VBE1, as consortia*, used in the present study were capable of degrading branched alkane isoprenoids such as pristine (C17) and pyrene (C18) present in PAHs contaminated soil with high lipase production. The fungal consortia acts as potential candidate for bioremediation of PAHs contaminated environments.

Vishwanath et al., 2014. Laccases are blue multicopper oxidases, which catalyze the monoelectronic oxidation of a broad spectrum of substrates, for example, *ortho*- and *para*-diphenols, polyphenols, aminophenols, and aromatic or aliphatic amines, coupled with a full, four-electron reduction of O_2 to H_2O. Hence, they are capable of degrading lignin and are present abundantly in many white-rot fungi. Laccases decolorize and detoxify the industrial effluents and help in wastewater treatment. They act on both phenolic and nonphenolic lignin-related compounds as well as highly recalcitrant environmental pollutants, and they can be effectively used in paper and pulp industries, textile industries, xenobiotic degradation, and bioremediation and act as biosensors. Recently, laccase has been applied to nanobiotechnology, which is an increasing research field, and catalyzes electron transfer reactions without additional cofactors. Several techniques have been developed for the immobilization of biomolecule such as micropatterning, self-assembled monolayer, and layer-by-layer techniques, which immobilize laccase and preserve their enzymatic activity. In their review, Vishwanath et al., (2014) described the fungal source of laccases and their application in environment protection.

Mrinalini Kumari and Jayanthi Abraham, 2011 reported that Yeast *Rhodosporidium toruloides* was isolated from soil contaminated with petroleum hydrocarbons from Vellore, India. Yeast strain showed 99% sequence similarity with *Rhodosporidium toruloides*. *In vitro* study to check the efficiency of indigenous yeast to degrade hydrocarbon present in diesel oil was done in shake flask. Isolated yeast was enriched in mineral salt media containing diesel oil as sole source of carbon. It utilized hydrocarbons present in diesel oil efficiently. Degradation was preliminarily determined by change in physical appearance of medium viz., colour and viscosity. Degradation of hydrocarbons present in diesel oil was further confirmed by gravimetric analysis and gas chromatography. Residual oil after 15 days of degradation period was quantified gravimetrically and subjected to gas chromatography with flame ionization detector analysis. Chromatogram obtained after GC analysis clearly showed degradation of hydrocarbons present in diesel oil.

Karigar & Rao (2011) reviewed that a large number of enzymes from bacteria, fungi, and plants have been reported to be involved in the biodegradation of toxic organic pollutants. Bioremediation is a cost effective and nature friendly biotechnology that is powered by microbial enzymes. The research activity in this area would contribute towards developing advanced bioprocess technology to reduce the toxicity of the pollutants and also to obtain novel useful substances (Masih & Charles, 2016). The information on the mechanisms of bioremediation-related enzymes such as oxido-reductases and hydrolases have been extensively studied. This review attempts to provide descriptive information on the enzymes from various microorganisms involved in the biodegradation of wide range of pollutants, applications, and suggestions required to overcome the limitations of their efficient use. Julia K et al. (2019) has documented their studies in enzymatic bioweathering and Metal Mobilization From Black Slate by the Basidiomycete Schizophyllum commune.

Enzyme hydrolyses has also been found to be involved in the process of bioremediation. Microbial breakdown and environmental reactions like hydrolysis, a peculiar feature of lipases and esterases, can renovate toxic compounds into less toxic compounds. Bioremediation using these hydrolytic enzymes is a usually safe, cheaper, and eco-friendly system in eliminating the pollutants from the environment. The present review attempts to afford descriptive information on the lipases/esterases sourced from a number of microorganisms involved in the biodegradation of a broad series of pollutants (Abhishek et al 2019)

BIO-SORPTION OF HEAVY METALS BY YEASTS

Several methods are being used for the removal of heavy metal ions from aqueous wastes like chemical precipitation, ion exchange, electrochemical treatment, membrane technologies, adsorption on activated carbon etc. Each of these methods has its own merits and demerits. While chemical precipitation and chemical treatments are ineffective, especially when metal ion concentration in aqueous solution is lower than 50mg/L, the ion exchange, membrane technologies and activated carbon adsorption processes are extremely expensive. Therefore biosorption has emerged out to be a very cost effective technology for the heavy metal removal.

The mechanism of metal adsorption is a complicated process. The status of biomass(living or dead), type of biomaterials, properties of metal solution chemistry, ambient/ environmental conditions such as pH, influence the mechanism of metal biosorption. The metal biosorption process by living cell is a two step process. In the first step, metal ions are adsorbed to the surface of cells by interactions between metals and functional groups displayed on the surface of the cells. The first step is passive biosorption, is metabolism independent and proceeds rapidly by any one or the combination of the following metal binding mechanisms like co-ordination complex formation, ion exchange, physical adsorption or inorganic micro precipitation. The second step due to active adsorption metal ions penetrate the cell membrane and enter into the cells.

Raj Mohan et al, 2011 reported that Heavy-metal pollution represents an important environmental problem due to the toxic effects of metals, and their invasion in to the food chain leads to serious ecological and health problems. Metal remediation through common physico-chemical techniques is expensive and unsuitable in treating large contaminated area effectively. Bioremediation offers a promising means to reclaim such contaminated soil in an economical and eco friendly way. Bioremediation employs microorganisms capable of degrading toxic contaminants or have the ability to accumulate it in their cells. This concentrated end product can afterwards be directed for a controlled way for recovery of metals. In their study *Saccharomyces cerevisiae* was used for the removal of heavy metals like Lead and Cadmium from contaminated soil. The tolerance of *Saccharomyces cerevisiae* against the metals was found to be upto 250 ppm and for Pb 2+, 500 ppm for Cd2+. The parameters affecting the biosorption of heavy metals; such as time, metal concentration and biomass concentrations have been investigated. The results revealed that biosorption of about 67-82% of Pd2+ and 73-79 % of Cd2+ was attained within 30 days. The time taken for maximum sorption of Pb2+ and Cd2+ was 30 days for soil containing 100 and 300 ppm of Pb2+ and Cd2+ respectively. Biosorption rate was higher when the cells were in stationary phase. The biosorption and the growth of the microorganism in aerated soil were found to be more comparing to non-aerated soil.
Abhishek et al. 2018. have studied and reported about the Low-Abundance Members of the Firmicutes Facilitate Bioremediation of Soil Impacted by Highly Acidic Mine Drainage From the Malanjkhand Copper Project, India

Cho and Kim, (2003) The yeast *Rhodotorula glutinis* was examined for its ability to remove Pb2+ from aqueous solution. Within 10 min of contact, Pb2+ sorption reached nearly 80% of the total Pb2+ sorption. The optimum initial pH value for removal of Pb2+ was 4.5–5.0. The percentage sorption increased steeply with the biomass concentration up to 2 g/l and thereafter remained more or less constant. Temperature in the range 15–45°C did not show any significant difference in Pb2+ sorption by *R. glutinis*. The light metal ions such as Na+, K+, Ca2+, and Mg2+ did not significantly interfere with the binding. The Langmuir sorption model provided a good fit throughout the concentration range. The maximum Pb2+ sorption capacity q max and Langmuir constant b were 73.5 mg/g of biomass and 0.02 l/mg, respectively. The mechanism of Pb2+ removal by *R. glutinis* involved biosorption by direct biosorptive interaction with the biomass through ion exchange and precipitation by phosphate released from the biomass.

BIO-SURFACTANT STUDIES

The process of bioremediation is based on the ability of microorganisms to assimilate and biodegrade petroleum or crude oil by using the hydrocarbon compounds as main carbon sources in specific metabolic pathways. The final products of this metabolism are sometimes represented by biosurfactants, surface-active molecules produced on the surface of cells whose diverse structure allows them to reduce surface and interfacial tension and to mediate the assimilation of hydrophobic substrates, including hydrocarbons, at the surface of cells (Kaya et al., 2014). Therefore, the development of knowledge concerning the structure and production of biosurfactants is important for the improvement of bioremediation technologies in oil recovery, agriculture, cosmetics, therapeutics, and microbial lipase production .

It has been reported that the yeast strains belonging to the Candida, Pichia, Rhodotorula, and Yarrowia genera are successfully used in biotechnology domains related to the food and chemical industries, therapeutics, and bioremediation. Csutak & Vassu (2014a & b) reported that the isolation and phylogenetic analysis of new yeast strains represent an important basis for the development of practical applications in biotechnology, industry, and bioremediation. The yeast strain RG1 was isolated from oil-polluted soil and characterized using morphological observations and the API 20C AUX system. The amplified ITS1-5.8S rDNA-ITS2 region had 653 bp and the restriction profiles obtained with *Cfo* I, *Dde* I, *Hae* III, *Hinf* I, and *Hpa* II endonucleases showed high similarities with those from *Rhodotorula glutinis* reference strains. The phylogenetic tree based on the *Cfo* I patterns confirmed the classification of the strain RG1 as belonging to the *R. glutinis* species. The studies performed during the present work indicate the existence of different mechanisms of *n*-alkane assimilation and biodegradation in the RG1 cells and their correlation with the production of biosurfactants. An evaluation of the emulsifying activity revealed that biosurfactant-mediated assimilation of *n*-alkanes decreases in the order *n*-decane > *n*-tetradecane > *n*-hexadecane. Biodegradation and emulsification assays using culture media supplemented with 1% *n*-alkanes as the sole carbon source showed that *n*-tetradecane represented the optimal hydrocarbon substrate for the growth of the strain RG1 over 14 days and for obtaining biosurfactants at stable rates.

BIOACCUMULATION

Li C, et al. (2014) reported that bioaccumulation via growing cells is a potential technique for heavy metal removal from food materials. The cadmium bioaccumulation characteristics by growing *Zygosaccharomyces rouxii* and *Saccharomyces cerevisiae* were investigated. *Z. rouxii* displayed powerful cadmium removal ability at low cadmium concentrations, which mainly depended on the intracellular cadmium bioaccumulation. The percentage of intracellular cadmium bioaccumulation of both yeasts obviously decreased with the increase of initial biomass and cadmium concentrations. Low pH and elevated concentrations of zinc and copper significantly decreased the intracellular cadmium bioaccumulation of both yeasts but improved the cadmium tolerance and the cell-surface cadmium bioaccumulation of *Z. rouxii*. Cadmium removal of Z. rouxii was improved by zinc and copper conditionally. *Z. rouxii* that possessed more powerful cadmium tolerance and removal ability at low pH and high concentration of competing ions can be developed into a potential cadmium removal agent using in complex food environment in future.
Massoud et al.(2019) also in their studies found the positive impact of *Saccharomyces Cervisae* in Cu ion bioremediation.

SYNERGISTIC EFFECT OF YEAST & BACTERIA

Zang et al., (2014) The effects of various treatments, including bio-stimulation, bio-augmentation with bacterial consortium, yeast, and yeast-bacterial co-culture, on oil biodegradation were systematically compared. Synergistic effects were observed on the removal of total petroleum hydrocarbon and polycyclic aromatic hydrocarbons via the amendment of co-culture, with a 48-day degradation of 56% for total petroleum hydrocarbon and 32% for polycyclic aromatic hydrocarbons, respectively. Yeast played an important role in the removal of polycyclic aromatic hydrocarbons with 4–6 rings. The synergistic effect of yeast-bacteria was further evidenced by the increase of biomass and enzyme activities in soil. In comparison with the bacterial community, the yeast community was more sensitive to the inoculated cultures, which was indexed by the changes of diversity, abundance, and evenness in polymerase chain reaction–denaturing gradient gel electrophoresis analysis.

Tamer et al., (2014) reported that organophosphorous nematicides are highly toxic pesticides used to control nematodes in agriculture soil. An in vitro Biodegradation study was conducted to determine the biodegradability of, ethoprophos, fenamiphos and triazophos nematicides, using fungi strains isolated from sandy agriculture soil under date palm trees. Five fungi strains labeled as S1 (*Fusarium oxysporum), S2 (Aspergillus flavus), S3 (Aspergillus fumigatus), S4 (Fusarium moniliforme) and S5 (Trichothecium roseum)* were isolated and identified, then incubated with nematicides at successive intervals untill 45 days in liquid medium paralleled with control samples. Recovery rates were performed at two levels 0.1 and 1 mg/ kg, values were over 90% for all nematicides. Data indicated that S1 *(Fusarium oxysporum)* and S2 *(Aspergillus flavus)* accelerated the degradation rate of all mentioned nematicides, and S2 had the highest impact more than S1, while the other strains had no significant effect. Half-life values (RL 50) for nematicides with S1 were 18.15, 16.65 and 15.24 days, respectively, and with S2 were 10.35, 13.87 and 11.18 days, respectively, while control values were 26.30, 24.28 and 26.70 days, respectively.

STUDIES ON THE METAL TOLERANT STRAINS OF YEAST

(Trama et al., 2014) The influence of xenobiotic compounds on environment and on living organisms has been reported as an imminent public health problem. Among them we can list the contamination by Alkanes present in petroleum, hydrocarbons and organic contaminant substances from industrial effluents. Also, heavy metals are of particular interest because of their persistence in the environment contaminating the food webs. Among the innovative solutions for treatment of contaminated water and soil is the use of biological materials like living or dead microorganisms. Yeasts exhibit the ability to adapt to extreme condition such as temperature, pH and levels of organic and inorganic contaminants that make them a potential material to be used to remediate contaminated environment application. Trama et al.(2014) in their search for yeast isolates capable to use n-hexadecane (alkane hydrocarbon) as a primary carbon source and for those able to tolerate high concentration of lead (Pb) within a collection of 90 isolates obtained from the Sao Paulo Zoo composting system. The isolated yeast strains were identified by mass spectrometry (MALDI-TOF-MS) and by sequencing of the ribosomal DNA (18S and D1/D2) conserved regions. They found that the collection bares 23 isolates capable of utilizing n-hexadecane and one which is able to tolerate high concentration of lead (Pb) with a high biosorption index compared to the reference yeast strains (BY4742, PE-2, CAT-1 and BG-1). These results confirm the initial hypothesis that the Sao Paulo Zoo composting is the source for diverse yeasts species with biotechnological application potential. The yeast strains can be used for the bioremediation of soil.

Vadkertiova and Slavikova, (2006) The tolerance of seventy yeast strains belonging to 15 species, isolated from water and soil environments as well as from tree leaves, to four heavy metals-copper, zinc, nickel and cadmium were studied. It was found that the interspecific and intra-specific variations in metal tolerance among studied strains were considerable. The highest interspecific variations were observed toward copper and cadmium. The strains of the species *Sporobolomyces salmonicolor, Cryptococcus albidus, Cystofilobasidium capitatum, Saccharomyces cerevisiae*, and *Candida maltosa* belonged to the most sensitive ones. In general ascomycetous yeasts were more tolerant to heavy metals than basidiomycetous ones. The differences among strains that came from various natural sources were also found. The most sensitive yeast population originated from untilled soil whereas the most tolerant population was isolated from tree leaves. In another study
Matthews-Amune et al.(2012) found similar results.

In another study by Azeez et al., (2011) the soil distribution of heavy metals caused by municipal solid waste (MSW) deposition and its implications for MSW management system in emerging cities was investigated in Abeokuta, Nigeria. Results indicated that the highest concentrations of Cu, Cr, Mn, and Zn were observed at 0-40 cm while Pb, Fe, and Ni accumulated at depths below 40 cm. Soils affected by waste deposits from market and auto-mechanic sites showed high levels of Fe, Cr, Pb, Cu, Mn, and Zn. The accumulation of heavy metals in the soils was probably due to the formation of metal-organo-complexes. Therefore, source separation of MSW with proper management systems is proposed to improve the indiscriminate surface dumping practiced at present, while the use of wastes affected sites for cultivation should be discouraged.

Bioremediation is an interesting alternative for restoring the ecological equilibrium in polluted environments, based on microbial population dynamics and its ability to consume xenobiotics as carbon source. O Csutak et al. 2010 reported that the yeast species described as having biodegrading abilities belong especially to *Pichia, Rhodosporidium, Rhodotorula, Trichosporon and Yarrowia.* Successful bioremediation require knowledge on limiting factors such as pollutant composition and nature, microbial community structure, contaminants accessibility, physical state of hydrocarbons, temperature, nutrients and oxygen. Studies on yeasts able to use various petroleum components as sole carbon source, showed that their biodegradability decreases from n-alkanes to high molecular weight aromatic and polar compounds. The alkanes are mainly degraded using the monoterminal oxidation pathway through cytochrome P450 system, and transformed into fatty acids with the same length of the carbon chain. Extensive studies showed that there are more than 80 genes involved in obtaining the alkane specific phenotype. At present, bioremediation technologies may be applied ex situ, in situ or in combination with conventional technologies.

Chatterjee et al., (2011) in their study highlighted isolation, characterization and bio-adsorption strategy of a lead tolerant yeast strain designated BUSCY1 from industrial effluent of Chittaranjan Locomotive Workshop, Burdwan, West Bengal, India. The isolate was found to grow best on yeast extract peptone sucrose (YEPS) medium (2% sucrose and 0.2% yeast extract found to be optimum for growth) with profuse production of extra cellular polymeric substance and a reddish pink pigment at 30°C, pH 5.5. The strain could tolerate up to 8 mM lead nitrate. Preliminary analysis revealed that the exopolysaccharide may have some role in lead tolerance. Das et al., 2008 in their laboratory scale studies on removal of lead demonstrated that after 72 h of incubation amount of lead ions decreased in supernatant whereas the amount of lead ions increased in the yeast cell wash which indicated bio-adsorption by the yeast strain. The strain was identified as *Rhodotorula mucilaginosa* based on morphological, physiological, biochemical tests and molecular phylogenetic analysis of partial 26S rDNA molecule.

CONCLUSION

Bioremediation of soil can be efficiently and cost effectively done by using yeast species. Studies using the principles of biosorption, bioaccumulation, biosurfactants and PM bound enzymes have shown the effect of yeast on reducing the heavy metal content of the soil. Some bacterial strains have synergistically increased this effect. The metal tolerant species have been identified from the dumpsites and studies conducted on them have shown them to have a mutated gene to cope up the high metal stress. The same gene manipulated in other species can make them metal tolerant. These species, when allowed to grow in the dumpsites with high level of metal contaminant, can bio-remediate the sites.The ex situ studies can be conducted and then the same may be extended to the sites.

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