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The Impact of Environmental Bioremediation of Lead Using Lead Resistant Bacteria

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Abstract

Bioremediation is a new technology that uses naturally occurring microorganisms to degrade toxic heavy metals into less toxic form from contaminated site. The use of chemical by famers as a result of agricultural activities highly contributed to trigger the ecological system and lead to high increase of toxicity deposited in the soil, that contain heavy metals ions and hence, changed the microbial structure on the basis of function, and diversity that deteriorated the soil as well as decreased the growth of plant in the environment. Heavy metals are widespread pollutants of great concern due to their non-degradable and obstinately release from industries, domestic and agriculture by which the effluents are consequently discharged into the environment without prior treatments as guided by the pollution control board. Lead (Pb^{2+}) as major heavy metal contaminant that originate from soil, water, air as well as environment, is a toxic metal ion that affect human, animals, plants and microbes. The toxicity level of Lead was broadly studied globally due to its effects on human health as well as contaminating the environment. The Bioavailability of lead that accumulated in the soil affect environment as well as brain of children, the current technology is used to monitor heavy metal ions using biosensor from

ISSN: 0971-1260

Vol-22-Issue-17-September-2019

environment and industries. The use of conventional technologies for reducing or eliminating heavy metals ions that were frequently used using microbes due to inexpensive, effective to achieve bioaccumulation and biosorption, that can improve the quality of environment.

Key words: Heavy metals, toxicity, lead, bioremediation

INTRODUCTION

Bioremediation is a new technology that uses naturally occurring microorganisms to degrade toxic heavy metals into less toxic form from contaminated site [1]. According to a research by Naik & Dubey, describe the use of bioremediation as an alternative way used for abstracting a toxic contaminants from waste effluents release into the environmental by anthropogenic activities using super bug in cleaning up oil spills to decrease the toxicity of metals ions by minimising the environmental contaminant using remediation process (USGS 1997) [2]. Hence, the use of chemical by famers as a result agricultural activities highly contributed to trigger the ecological system and lead to high increase of toxicity deposited in the soil, that contain heavy metals ions and hence, changed the microbial structure on the basis of function, and diversity that deteriorated the soil as well as decreased the growth of plant in the environment [3]. The use of toxic heavy chemical that are released to cause hazardous toxins present in industrial and domestic waste water that will directly be related with environmental pollution and biological toxicity system [4]. Heavy metals are widespread pollutants of great concern due to their non-degradable and obstinately release from industries, domestic and agriculture by which the effluents are consequently discharged into the environment without prior treatments as guided by the pollution control board. Though some metals (Boron, copper, iodine, manganese, molybdenum, and zinc) are important trace elements that regularly be at high concentrations and

ISSN: 0971-1260

Vol-22-Issue-17-September-2019

lethal to all forms of life. Lead (Pb^{2+}) as major heavy metal contaminant that originate from soil, water, air as well as environment, is a toxic metal ion that affect human, animals, plants and microbes. The toxicity level of Lead were broadly studied globally due to its effects on human health as well as contaminating the environment [5, 6]. The lead toxicity can serve as the perseveres in environment that cannot be degraded or destroyed [7], the toxicity of heavy ions that has a severe harmful influence to human health and affect the environmental flora as well as damage the central nervous system of the brain that resulted in serious low IQ depression in children and death, mostly in children do to the high level of absorption compare to adults [8].

The data recorded by WHO [9], it has been estimated that heavy lead metal ion effect resulted in one hundred and forty three thousand deaths, and contributed to six hundred thousand fresh cases of children each year with low intellectual ability. However, a research by [10], point out the level of lead impurity as a widespread delinquent in the world due to anthropogenic activity by industries and lead ore processing company. The Bioavailability of lead that accumulated in the soil affect environment as well as brain of children, the current technology is used to monitor heavy metal ions using biosensor from environment and industries. The use of conventional technologies for reducing or eliminating heavy metals ions that were frequently used using microbes due to inexpensive, effective to achieve bioaccumulation and biosorption, that can improve the quality of environment [11].

These research will focus on the new modern technology by using microorganisms in solubilizing the toxic heavy metals into less toxic form thereby immobilizing them using bacteria that could find option for detoxifying the heavy metals in the environment through the use of

ISSN: 0971-1260

Vol-22-Issue-17-September-2019

some bacteria species that are resistant bacterial strains capable of modifying the contaminant into non-toxic form [12].

Bioremediation

Bioremediation is a modern technology use to convert toxic heavy pollutant into a less harmful using microorganisms to clean-up polluted soil and water environment that contain heavy metal. that contaminate environment [13]. A research review by [2] highlight the significance of Bioremediation as a prospective for environmental safety. The present research will use different mechanisms that will engaged to show how bacteria can resist to high levels of lead toxicity and solubilize it into non-toxic using microbes which is one of the key factor in bioremediation process [13]. This dissertation will focus on the use of bacteria that will be resistant to toxicity of Lead (Pb2+) with the severe negative effect in remediation process for human health and environment by improving the Physical, chemical and biological remediation techniques to remediate lead contamination, as well as eco-friendly method to reduce lead contamination [7].

Historical background

Bioremediation was first studied in 1940 but it well-known in the year 1980 by the U.S. and was used as a new modern technology to sanitize the contaminated oil spills in the environment, by the year 1960 George M. Robinson developed the new process and planned the first large scale microbial oil spill remediation in 1968. In 1970 a famous scientist Chakraborty was discovered a bacterium strain that remediate the oil spill. Concurrently in 1975 he discovered the superbug and was granted a patent for his discovery. However, Exxon development of Valdez oil spill that was clean in 1989 by Prince William expanded the attention that has been used in many location. A review article paper published in 1970 and 1980 respectively covered the mechanisms of

ISSN: 0971-1260

Vol-22-Issue-17-September-2019

remediation information happened at Amoco Cadiz oil degradation. The use of bioremediation method has not been applied to any major oil spill in the United States between 1989 and 1991 respectively, but got huge attention toward implementing the new developed protocols by the United States on "Environmental Protection Agency". The system develops many laboratory and field study to find the potentiality of remediation process. Lastly by the year 1990 bioremediation was tested in four oil spills in the United States and considered in 1992 as the bioremediation center.

Lead

The toxic effect of lead that contributed on the environmental contamination were known by the ancients Greek botanist Nicander in the second century who observed the colic and paralysis caused of lead in the society. Likewise a Greek physician Dioscorides who lived in the first century wrote the extensive toxic effect of lead in Roman aqueducts around 500 BC to 300 AD. But Julius Caesar stated that water in pipes is much healthier from earthenware than from lead pipes because the white lead cause detrimental effect to the human body. As reported 2013 by "World Health Organization", estimated that lead is responsible for almost one hundred and forty three thousand death each year [9].

The neurotoxin effect that cause the accumulation in soft tissues and bones causes damages to the nervous system and inhibits the function of biological enzymes that affect the neurological disorders and brain damage in children. In the late 19th century the application and uses of lead was recognized by many countries and still allow the sale of products; like paints and bullets due to its stability in nature [14].

ISSN: 0971-1260

Vol-22-Issue-17-September-2019

Bioremediation

Is a method that use naturally occurring biological microorganism to remove toxic waste from environment using bacteria by reducing the contaminated toxicity of soil and water into less toxic form as an effective management tool in monitoring environmental pollution and recover soil contamination worldwide with varying degrees of success [15]. The process can be achieved using an in-situ and ex-situ bioremediation strategy to reduce the soil contamination from heavy metals ions by removing the metal from contaminated environment and treated using resistant soils bacteria [16], the method considered as promising alternative by the current available bioremediation practices for easy implementation and application to a wide range of polluted sites as a tool mechanism [17].

In-Situ Bioremediation

The In situ bioremediation is a method used to clean up aquifers and soil contaminated environment using organic chemicals like hydrocarbons and chlorinated solvents for remediation purpose, but require the supply of oxygen and nutrients to stimulate naturally occurring bacteria in the degradation process of heavy metals contaminants [16]. The in-situ bioremediation consist of intrinsic and engineered bioremediation.

I- Intrinsic bioremediation

Is a method that bring about the essential skills used by naturally occurring microbes to degrade pollutants without taking any engineering steps and determining the contamination fate in groundwater and to assess its effects through the occurrence of natural contaminant degradation processes that leads to the decrease of groundwater contamination [18].

ISSN: 0971-1260

Vol-22-Issue-17-September-2019

II- Engineered In situ bioremediation

Is a remediation procedure use to enhance the growth and degradable activity of bacteria by using genetically modified organisms to source nutrients and use electron acceptors and other growth promoting tools anaerobic treatments for hydrocarbon to improve degradation that yields the engineered in-situ methods or chemical modifications that commonly useful in order to remediate the groundwater and soil, the use of solid and liquid peroxides in hydrocarbon especially hydrogen peroxide and is most widely used product though the treatment is inexpensive and also non-persistent [19].

Ex-Situ Bioremediation

It is a biological method that mined soil is placed above the ground treatment aerated condition to increase the removal of organic contaminants using indigenous bacteria under aerobic conditions. The use of specific bacteria can utilize and reduced the organic contaminants of petroleum hydrocarbon mixtures, polycyclic aromatic hydrocarbons and some pesticides used as the source of carbon and energy that degrade these components ultimately to carbon dioxide and water.

i- Solid phase method

The solid phase method consist of organic wastelands such as leaves, animal manures, industrial wastes, domestic, sewage sludge and municipal solid wastes, land farming, soil bio piles, and composting.

ii- Slurry phase methods

Slurry bioremediation phase is a speedy process compared to solid phase whereby the polluted soil merged microorganisms in a large tank known as bioreactor that are used for mixing and

ISSN: 0971-1260

Vol-22-Issue-17-September-2019

keep the bacteria already present and also interact with the toxins present in the bioreactor of soil follow by the addition of nutrients and oxygen in the bioreactor to measured and create an ideal conducive environment for microorganisms to degrade the toxic metal ions [20].

2.4.3 Bio stimulation

Bio stimulation is an adjustment of environmental microorganisms capable of remediating heavy metals that accumulate in the environment by adding inhibitor that act as rate limiting nutrients and electron acceptor such as carbon, nitrogen, phosphorus,and oxygen that increase the activity of native microorganisms available for bioremediation through injection of either liquid or gaseous form in the remediation process [1].

Biostimulation is dependent on the indigenous organisms and thus requires that they be present and that the environment be capable of being altered in a way that will have the desired bioremediation of organisms have been exposed to the contaminant for extended periods of time and have adapted or even naturally selected. Many contaminants, especially organic compounds are naturally occurring or have natural analogs in the environment. Rarely can a terrestrial subsurface environment be found that does not have a number of organisms already present that can degrade or transform any contaminant present. Indeed, even pristine environments have bacteria with an increasing number of plasmids with sediment depth in response to increasing recalcitrance of the organics present [21].

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ISSN: 0971-1260

Vol-22-Issue-17-September-2019

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Bioaugmentation

Bio augmentation is the accumulation of grown bacteria that can easily biodegrade contaminated heavy metal ions by continuous monitoring of the bioreactor for ground water treatment that colonize contaminated environments whereby intrinsic microbial populations act on heavy metals ions.

Functions of microbial bioremediation

Microbial diversity of microbes involved bioremediation of specific pollutants and their modes of actions in designing bioreactors for efficient removal of pollutants to be achieved [22]. Irrespective of the cellular compounds involved. Microbes achieve bioremediation through;

Bio-sorption

Is the ability of resistant bacteria to remediate heavy metals ions from contaminated pollutant by metabolic mediation of adenosine triphosphate uptake of inactive non-living microbial biomass that bind to heavy metals ions unlike the complex method that depends on other metals; cadmium, silver, lead, and nickel by using bacteria to reduce the toxicity level.

ISSN: 0971-1260

Vol-22-Issue-17-September-2019

Complexation

Complexing capacity in bioremediation has been determined by stripping techniques in a wide range of situations by natural aquatic environments like sea and freshwater, industrial and domestic effluents, model ligand solutions, biological aqueous systems, blood and wine. In most cases, the studies have been focused on copper, while cadmium has received less attention.

Bioassimilation

Bio-assimilation and bioavailability using bacteria to remediate the toxicity of lead into less toxic which is very narrow in the aquatic environment especially near the sea floor that generally becomes steady or bound to organic complexes deposited in water and led to assimilation and bioaccumulation [23].

Limitation of bioremediation

The new modern technology using bioremediation method perceived by the public as an acceptable waste treatment process for resolving contaminant issue in the environment by use of bacteria to degrade and decrease the numbers of pollutant present as well as population declines using residues for the treatment.

Biosorption

Is the restoration of the positively charged heavy metal ions to the negatively charged membranes, a polysaccharides secreted in most of the bacteria membrane on the external surfaces formation [24].

Production of cheaper biomass

The use of bacteria for remediation of environmental pollutant

Accumulation of toxic heavy metals

ISSN: 0971-1260

Vol-22-Issue-17-September-2019

Treatment of large volumes of environmental pollutant

The Bioaccumulation method

Is the maintenance and absorption of bacteria reduce by their toxic heavy metals effluents release from outside of the bacterial cell membrane to cytoplasm.

Biologically catalyzed immobilization

Resistant bacteria have direct enzymatic function that contains the use of reduced form of heavy metals that will serve as electron donor Pb^{2+}. The oxidized forms of these metals are highly stable and hence, led to the hazardous contamination of the groundwater contamination in the soil.

Biologically catalyzed solubilization

The process of biosorbed and co-precipitated of metals by direct or indirect microbial processes of toxic heavy metals solubilize by resistant metal bacteria that requires partial solubilization of the oxide mineral.

Lead resistance bacteria Mechanism

The use of resistant bacteria for remediating heavy metal ion mechanisms have developed numerous resistivity that can be restrain, assemble or transform the toxic microbes, by reducing their toxicity to allow heavy metal ion uptake [25]. These mechanisms include the use of resistant bacteria that resist the activity of extracellular polymers to efficiently bind to heavy metals and reduce their toxicity by simple complex formation of an effective barrier in surrounding environment that can reduce metal bioavailability and its toxicity through binding to metal ions.

ISSN: 0971-1260

Vol-22-Issue-17-September-2019

Mechanisms and detoxification of heavy metal

This mechanism that adapt the use of bacteria and interact in the presence of heavy metals used by bacteria to persist metal toxicity in the environment that can disinfect metals by valence conversion, volatilization, or extracellular chemical precipitation [13].

Mechanisms of biosorption

The use of toxic heavy metals by bacteria through bio-sorption mechanisms mostly occurs on the external cell and absorption of bioaccumulation pollutants in the environment by redox reaction and species transformation of bacteria through surface complexation.

Intracellular Sequestration

The use of bacteria enhance resistance the resistivity of toxic effects by heavy metals ions and organo metals by the mechanisms of specific metal binding proteins facilitating the sequestration and accumulation of toxic metals in an environment [2], and some unique proteins shows a reaction to specific heavy metals [26].

Extracellular Sequestration

Toxic metals is an essential aspect that use microbes to regulate metal toxicity and solubilize them that can readily infiltrate into cellular membranes [27], the metal that immobilize the strategy that will be applied by bacteria to counteract with toxic effects of heavy metals ion 28..

Bio precipitation

The precipitation of toxic heavy metals to insolubilize and decreases the bioavailability and toxicity using lead resistant bacteria [29], that precipitate the lead on the cell surface using microanalysis. According to [30], suggested that intracellular accumulation and precipitation of lead occurred in both lead sensitive and lead resistant strains [29].

ISSN: 0971-1260

Vol-22-Issue-17-September-2019

Surface bio-sorption

The mechanism involves for extracellular sequestration of toxic heavy metals that inhibit the entry of microbes for preserving the metal stability mediated by several mechanisms [31]. A research shows the surface of bio sorption due to present of peptidoglycan layer of bacteria that resist the toxicity of heavy metal ions and serve as metal binding site [32].

Cell morphology and alteration

The frequent exposure of environmental contamination and organic compounds by the use of resistant bacteria to stabilize and exhibit significant modifications in cell that will Change bacteria to adopt environmental stresses morphology [33], this shows the maximum modifications of lead and cadmium..

Pigments detoxification in metal

The bacteria Pigmented are predominant in areas with less contamination of organic pollutants with heavy metals and high salt concentrations [34]. The use of lead resistant bacteria by chemically distinct iron chelators that are transported into the bacterial cells via specific receptors metals and influence the metal mobility in the soil to isolate toxic heavy metals [35].

Organo lead biotransformation

The use of organo lead compounds tetraethyl and tetra methyl are the most steady and essential method widespread use as an anti-knocking of petrol [36], the high level use of leaded gasoline from atmosphere and automobile exhaust are released as lead halides.

Methylation of Metals toxicity

The level of methylation increases metal toxicity as an effect of improving the lipophilicity and thus increased invasion through the cell membranes using lead resistant bacteria which enhances

ISSN: 0971-1260

Vol-22-Issue-17-September-2019

the remediation process by methylating the compounds that are regularly explosive and can easily be methylated by such resistant bacteria [37].

Heavy metal ions reduction using microbial cell

The use of resistant bacteria can easily increase metal ion toxicity from one oxidation state to another by reducing their toxicity, microorganisms use metals and metalloids as electron donors or acceptors for energy generation and the metals in the oxidized form can serve as terminal acceptors of electrons during anaerobic respiration of bacteria to degrade the heavy metal ions into less toxic[31].

Prevention of metal entry into microbial cell

The plasma membrane of cell wall and capsule serve to prevent metal ions from entering into bacteria cell that can adsorb metal ions by ionizable groups of the cell wall [38].

Microbial biosensors for monitoring pollution

The use of microbial biosensor for monitoring toxicity level of heavy metals ions using bacteria produce a specific measurable return in response to target chemicals that use by bacterial cell to established a convenient biological device for monitoring and quantifying heavy metal contaminants in environment [38].

The use of fungi for bioremediation

The use of Fungi in bioremediation is a widely used method of biosorbents for the elimination or reduce of toxic heavy metal ions into nontoxic form for metal uptake and recovery of inorganic chemicals [39]. Similarly a research by [40], reported the efficiency where resistant bacterial use for the removal of heavy metal ions in environment using a specific pH and temperature in a bioreactor system from the effluent release that hinder the growth of the organism [41].

References:

1. Ramasamy, K., & Banu, S. P.. Bioremediation of Metals : Microbial Processes and Techniques (1997).

2. Naik, M. M., & Dubey, S. K.. Lead resistant bacteria: Lead resistance mechanisms, their applications in lead bioremediation and biomonitoring. Ecotoxicology and Environmental Safety, 98, 1–7 (2013).

3. Etesami H, Maheshwari DK, "Use of plant growth promoting rhizobacteria (PGPRs) with multiple plant growth promoting traits in stress agriculture: Action mechanisms and future prospects". Ecotoxicol Environ Saf. 30;156:225-246, 2018.

4. Gupta Mahendra K., Kumari Kiran, Shrivastava Amita and Gauri Shikha, Biore mediation of heavy metal polluted enviro nment using resistant bacteria, J. Environ. Res. Develop., 8(4), 883-889, (2014).

5. Yabe J, Shouta M.M. Yoshinori N, Yoshinori I "Lead poisoning in children from townships in the vicinity of a lead-zinc mine in Kabwe, Zambia"Chemosphere 119C:941-947, 2014.

6. Lin, M., Gui, H., Wang, Y., Peng, W., Pollution characteristics, source apportionment, and health risk of heavy metals in street dust of Suzhou, China. Environ. Sci. Pollut. Res. Int. 24, 1987–1998, 2017.

7. Mwandira, W., Nakashima, K., & Kawasaki, S.. Bioremediation of lead-contaminated mine waste by Pararhodobacter sp . based on the microbially induced calcium carbonate precipitation technique and its e ff ects on strength of coarse and fi ne grained sand. Ecological Engineering, 109(September), 57–64 (2017).

8. Bruce P. Lanphear, Richard Hornung, Jane Khoury, Kimberly Yolton, Peter Baghurst, David C. Bellinger, Richard L. Canfield, Kim N. Dietrich, Robert Bornschein, Tom Greene, Stephen J. Rothenberg, Herbert L. Needleman, Lourdes Schnaas, Gail Wasserman, Joseph Graziano, and Russell Roberts," Low-Level Environmental Lead Exposure and Children's Intellectual Function: An International Pooled Analysis" Environ Health Perspect. Jul; 113(7): 894–899 2005.

9. Rajeswari, T. R. Impact of heavy metals on environmental pollution. (3), 175–181 (2014).

10. Chatterjee C, Dube BK, Sinha P, Srivastava P Detrimental effects of lead phytotoxicity on growth, yield, and metabolism of rice. Commun Soil Sci Plant Anal 35(1–2):255–265, (2004).

11. Farida Mohamed El BazFarida Mohamed El BazBaz MohamedEman Ahmed ZakyEman Ahmed "Assessment of Hair Aluminum, Lead, and Mercury in a Sample of Autistic Egyptian Children: Environmental Risk Factors of Heavy Metals in Autism" Behavioural neurology (3) 2015.

ISSN: 0971-1260

Vol-22-Issue-17-September-2019

12. Lovley DR. Microbial fuel cells: novel microbial physiologies and engineering approaches. Current Opin Biotechnol 17: 327–332 (2006).

13. Igiri, B. E., Okoduwa, S. I. R., Idoko, G. O., Akabuogu, E. P., Adeyi, A. O., & Ejiogu, I. K. (2018). Toxicity and Bioremediation of Heavy Metals Contaminated Ecosystem from Tannery Wastewater : A Review. 2018.

14. Fashola, M. O., Ngole-Jeme, V. M., & Babalola, O. O.. Heavy metal pollution from gold mines: Environmental effects and bacterial strategies for resistance. International Journal of Environmental Research and Public Health, 13(11) (2016).

15. Strong PJ, Burgess JE.. Treatment methods for wine-related and distillery wastewaters review. Bioremedy Journal, 12: 70-87(2008).

16. Sun, Y., Li, Y., Xu, Y., Liang, X., & Wang, L.. In situ stabilization remediation of cadmium (Cd) and lead (Pb) co-contaminated paddy soil using bentonite. Applied Clay Science, 105–106, 200–206 (2015).

17. Garau, G., Castaldi, P., Santona, L., Deiana, P., & Melis, P.. Influence of red mud, zeolite and lime on heavy metal immobilization, culturable heterotrophic microbial populations and enzyme activities in a contaminated soil. Geoderma, 142(1–2), 47–57 (2007).

18. Hooker, B. S., & Skeen, R. S.. Intrinsic bioremediation: An environmental restoration technology. Current Opinion in Biotechnology, 7(3), 317–320 (1996).

19. Menendez-Vega, D., Gallego, J. L. R., Pelaez, A. I., Fernandez de Cordoba, G., Moreno, J., Muñoz, D., & Sanchez, J.. Engineered in situ bioremediation of soil and groundwater polluted with weathered hydrocarbons. European Journal of Soil Biology, 43(5–6), 310–321 (2007).

20. Kumar, A., Bisht, B. ., Joshi, V. ., & Dhewa, T.. Review on Bioremediation of Polluted Environment : A Management Tool. International Journal of Environmental Sciences, 1(6), 1079–1093, (2011).

21. Barbara L Fredrickson Roberta A Mancuso Christine Branigan Michele M Tugade Michele M Tugade “The Undoing Effect of Positive Emotions” Motivation and Emotion 24(4):237-258, 2000.

22. Kapagunta, B. C., & Majumder, A.. Importance of bioremediation and its future prospects Microbes are an efficient tool for bioremediation technology Functions of microbial bioremediation Emerging trends in bioremediation. 1–5 (2019).

23. R. Zhang, J.M. Vivanco, Q. Shen “The unseen rhizosphere root–soil–microbe interactions for crop production” Curr. Opin. Microbiol., 37, pp. 8-14 (2017).

24. A. Gupta, P. Bhatnagar, P.P. Bakre Physicochemical properties of water and heavy metals (lead and zinc) in water and sediment of a reservoir and drainage of Jaipur (Rajasthan) – a comparative study Int. J. Fish. Aquatic Studies, 4 (5) (2016), pp. 407-412, (2016).

25. Rajkumar, M., Ae, N., Prasad, M. N. V., & Freitas, H.. Potential of siderophore-producing bacteria for improving heavy metal phytoextraction. Trends in Biotechnology, 28(3), 142–149. (2010).

26. Blindauer, C. A., Harrison, M. D., Robinson, A. K., Parkinson, J. A., Bowness, P. W., Sadler, P. J., & Robinson, N. J.. Multiple bacteria encode metallothioneins and SmtA-like zinc fingers. Molecular Microbiology, 45(5), 1421–1432 (2002).

27. Roane, T. M.. Lead resistance in two bacterial isolates from heavy metal-contaminated soils. Microbial Ecology, 37(3), 218–224 (1999).

28. Bramhachari, P. V., Kavi Kishor, P. B., Ramadevi, R., Kumar, R., Rama Rao, B., & Dubey, S. K.. Isolation and characterization of mocous exopolysaccharide (EPS) produced by Vibrio furnissii strain VB0S3. Journal of Microbiology and Biotechnology, 17(1), 44–51 (2007).

29. Levinson, H. S., & Mahler, I.. Phosphatase activity and lead resistance in Citrobacter freundii and Staphylococcus aureus. FEMS Microbiology Letters, 161(1), 135–138 (1998).

30. Shim, J., & Om, A.. Biosorption of Lead (Pb2+) by using Chlorella vulgaris. 4(2), 1–10 (2008).

31. Volesky, B.. Advances in biosorption of metals: Selection of biomass types. FEMS Microbiology Reviews, 14(4), 291–302 (1994).

32. Gadd, G. M.. Heavy metal accumulation by bacteria and other microorganisms. Experientia, 46(8), 834–840 (1990).

33. Neumann, G., Veeranagouda, Y., Karegoudar, T. B., Sahin, Ö.¨, Mäusezahl, I., Kabelitz, N. Heipieper, H. J. Cells of Pseudomonas putida and Enterobacter sp. adapt to toxic organic compounds by increasing their size. Extremophiles, 9(2), 163–168 (2005).

34. Nair, S., Chandramohan, D., & Loka Bharathi, P. A.. Differential sensitivity of pigmented and non-pigmented marine bacteria to metals and antibiotics. Water Research, 26(4), 431–434. (1992).

35. Zanardini, E., Andreoni, V., Borin, S., Cappitelli, F., Daffonchio, D., Talotta, P., … Cariati, F. Lead-resistant microorganisms from red stains of marble of the Certosa of Pavia, Italy and use of nucleic acid-based techniques for their detection. International Biodeterioration and Biodegradation, 40(2–4), 171–182 (1997).

36. Jarvie, A. W. P.. Organoleads in the environment: A review. Science of the Total Environment, The, 73(1–2), 121–126 (1988).

ISSN: 0971-1260

Vol-22-Issue-17-September-2019

37. Ridley W P, Dizikes W P, Wood J M "Biomethylation of Toxic Elements in the Environment" Science (4301):329-32, 1977.

38. Hynninen, A., Tõnismann, K., & Virta, M. Improving the sensitivity of bacterial bioreporters for heavy metals. Bioengineered Bugs, 1(2), 132–138 (2010).

39. Vankar, P. S., & Bajpai, D. Phyto-remediation of chrome-VI of tannery effluent by Trichoderma species. Desalination, 222 (1–3), 255–262, (2008).

40. Srivastava, S., & Thakur, I. S.. Isolation and process parameter optimization of Aspergillus sp. for removal of chromium from tannery effluent. Bioresource Technology, 97(10), 1167–1173 (2006).

41. Biochemistry, P. Bioaccumulation of Copper (II), Lead (II) and Chromium (VI) by Growing Aspergillus niger Bioaccumulation of copper (II), lead (II) and chromium (VI) by. 9592 (August 2014), 4–9 (2003).