

Biosorption of Lead by *Beauveria bassiana*

Tyagi S and Tyagi A*

Department of Biotechnology, Meerut Institute of Engineering and Technology, Meerut, Uttar Pradesh, India

***Corresponding author:** Anjali Tyagi, Department of Biotechnology, Meerut Institute of Engineering and Technology, Meerut, Uttar Pradesh, India, E-mail: anjalitg22@gmail.com

Received: February 25, 2017; **Accepted:** March 30, 2017; **Published:** April 10, 2017

Abstract

Heavy metal pollution is now a day's one of the most important natural concerns. Anthropogenic activities like metalliferous mining and smelting, agriculture, waste disposal or industry releases are variety of heavy metals which can produce destructive impacts on human wellbeing when they are taken up in amounts that cannot be handled by the organism. Damage may cause destructive reactions in different organs and biological functions, including reproduction and birth consequences. Various techniques have been employed for the treatment of industrial effluents, which usually include precipitation, adsorption, ion exchange, membrane and electrochemical technologies but these techniques are expensive, not environment well disposed.

Keywords: Biosorption; Metalliferous; Anthropogenic; Microbial ecology; Unicellular; Multicellular; Metal selective

Introduction

Microbiology is derived from Greece word "micro" which reflects "small"; & "bios" reflects "life", Microbiology is the study of microscopic organisms, those being unicellular, multicellular, or a cellular. Eukaryotic micro-organisms possess membrane-bound cell organelles include fungi and protists. Microbial ecology [1-6] is the relationship between microorganisms and their environment. Development in Microbial ecology gives rise to relatively new field of science and technology, discussing in Pollution Control Congress July 20-22,2017 Melbourne, Australia & Environmental Toxicology October 19-20,2017 Atlanta, USA. Microbiology [7-14] covers a broad spectrum of application in various fields such as health and medicine, and environment. Biosorption can be defined as the capacity of biological materials to accumulate heavy metals from waste water through metabolically mediated or physico-chemical pathways of take up. Algae, bacteria and fungi and yeasts have proved to be potential metal bio sorbents. The increase in the contamination of the aquatic system with heavy metals through industrial activities has started the search for economic strategies for their removal like, biodegradation and biosorption.

Biosorption is a physiochemical process that happens naturally in certain biomass which allows it to passively concentrate & tie contaminants onto its cellular structure [15,16]. Algae, bacteria and fungi have proved to be potential metal biosorbents. The biosorption [17-26] process involves a solid phase (biological material) and a fluid phase (solvent, normally water) containing a dissolved species to be sorbed (metal ions). To increase the development studies in field of microbiology certain

research associations are coming together to support new and challenging approaches using microbiological factors such as European Biotechnology Thematic Network Association (EBTNA) which aims to utilize Biotechnology and Microbiology tools for different applications in field of Medical, Environment, Healthcare, and Microbiology [27-35].

The pollution [36-39] of water due to heavy metals is an issue of great environmental concern. The significant advantages of biosorption over conventional treatment methods include:

- **Regenerative:** biosorbents can be reused, after the metal is recycled.
- **Cheap:** the cost of the biosorbent is low since they regularly are made from abundant or waste material.
- **Metal selective:** the metal absorbing performance of various types of biomass can be more or less selective on different metals. This relies on various factors such as type of biomass, mixture in the solution, type of biomass preparation and physicochemical treatment.
- **No sludge generation:** no secondary problems with sludge occur with biosorption, similar to the case with many other techniques, for example, precipitation.
- **Metal recovery possible:** in case of metals, it can be recovered in the wake of being sorbed from the solution.
- **Competitive performance:** biosorption is capable of a performance comparable to the most comparable procedure, ion exchange treatment.

Lead (Heavy Metal)

A heavy metal is a metallic component which is toxic and has a high density, specific gravity or atomic weight. Less commonly, any metal with a potential negative health effect or environmental impact may be termed a heavy metal [40-45], examples of heavy metals include lead, mercury, cadmium, cobalt, chromium, lithium and even iron. Of the important metals, Mercury, lead, cadmium, Arsenic and Chromium (VI) are regarded as toxic; whereas, others, such as copper, nickel, cobalt and zinc are not as toxic [46-50]. The heavy metal ions are detected in the waste streams [51,52] from mining operations, tanneries, electronics, electroplating, batteries and petrochemicals industries. They have harmful impact on human physiology and other biological systems when they exceed the tolerance levels. Lead deposited on the ground is transferred to the upper layers of the soil surface [53-56], where it may be retained for a long time (up to 2000 years). In undisturbed ecosystems, natural matter in the upper layer of soil surface retains environmental lead. In cultivated soils, this lead is mixed with soil to a depth of 25C11l (i.e., within the root zone). To highlight innovative researches in field of microbiology and environmental concern a number of research work is published under different Journals such as Bioremediation & Biodegradation, Expert Opinion on Environmental Biology and many more. All the write-ups submitted to the Journals provide a range of individual opportunities to acknowledge internationally. Atmospheric lead in the soil will continue to move into the micro-organism and grazing food chains, until equilibrium is reached [57-60].

Plants on land tend to absorb lead from the soil and retain most of this in their roots [61]. There is some evidence that plant foliage may also take up lead (and it is conceivable that this lead is moved to different parts of the plant). The uptake of lead

by the roots of the plant may be reduced with the application of calcium and phosphorus [62-66] to the soil. A few types of plant have the capacity to accumulate high concentrations of lead. Lead at the concentrations occasionally found near roadsides (i.e., 10,000 - 40,000 ppm dry weight), can wipe out populations of bacteria and fungi on leaf surfaces and in soil. This can have a significant impact, given that many of these micro-organisms are a fundamental part of the decomposing food chain. The micro-organism [67-72] populations influenced are likely to be replaced by others of the same or different species, although these may be less efficient at decomposing organic matter. Evidence also proposes that micro-organisms can make lead more soluble and hence more easily absorbed by plants. Lead affects the central nervous system of animals and inhibits their capacity to synthesize red blood cells. Lead blood concentrations of above 40µg/dl can produce observable clinical symptoms in domestic animals [73,74].

Lead has many different impacts e.g. acute abdominal pain, kidney damage, high blood pressure and adverse reproductive consequences etc. Lead salts enter the environment [75-80] through the exhausts of cars, autos. The larger particles will drop to the ground immediately and contaminate soils or surface waters, the smaller particles will travel long distances through air and stay in the atmosphere [81-84]. Part of this lead will fall back on earth when it is raining. This lead-cycle caused by human creation is much more extended than the natural lead-cycle. It has caused lead pollution to be a worldwide issue.

Lead can cause several unwanted effects, such as:

- Disruption of the biosynthesis of haemoglobin and anaemia
- A rise in blood pressure
- Kidney damage
- Miscarriages and subtle abortions
- Disruption of sensory systems
- Brain harm
- Declined fertility of men through sperm damage
- Diminished learning abilities of children
- Behavioural disruptions of children, such as aggression, impulsive behavior and hyperactivity

The presence of metal ions in final industrial effluents is extremely undesirable, as they are toxic to both lower and higher organisms. Under certain natural conditions, metals may accumulate to lethal levels and cause ecological damage.

Major lead pollution can occur through automobiles and battery manufacturing [85-89]. Lead particles that settle on the soil from leaded gasoline or paint can keep going for a considerable length of time. Lead-contaminated soil is still a noteworthy problem around highways and in some urban settings. Household dust can contain lead from lead paint chips or from contaminated soil brought in from outside. Glazes found on some ceramics, china and porcelain can contain lead that may leach into food. Heavy metals are toxic to aquatic organisms even at very low focus. Most of these minerals were present in our surroundings only in minute amounts until recent centuries, when the orientation toward industrialization and production brought about our numerous technological advances. But technology, like medicine, [90,91] has its side effects. At present, these harmful metals have polluted our atmosphere, our waters, our soil, and food chain. Approximately 98% of lead in the atmosphere is from human activities. Neumann et al. have extended the sources of lead pollution [92-95] by paints, lead wastes, cell batteries, lead solders and forms.

Beauveria bassiana

Beauveria bassiana is a fungus that grows naturally in soils throughout the world and acts as a parasite on various arthropod species, causing white muscardine disease; it thus belongs to the entomopathogenic fungi. The species is named after the Italian entomologist Agostino Bassi, who discovered it in 1835 as the cause of the muscardine ailments of domesticated silkworms. It was formerly also known as *Tritirachium shiotae*. The name *Beauveria bassiana* has long been used to describe a species complex of morphologically similar and closely related isolates. *Beauveria bassiana* is used as an inexpensive and efficient biodegradant for Pb(II) and Cd(II) from aqueous metal solutions [96,97]. The data obtained imply the potential role of *Beauveria bassiana* for heavy metal removal from aqueous solutions.

The white muscardine *Beauveria bassiana* fungus is a potential bio-control agent [98] that could be used against the berry borer very successfully. This pathogen, which kills the borer can be cultured at the estate level and sprayed on the infested plants.

Beauveria bassiana in the absence of a specific insect host grows through an asexual vegetative life cycle comprises of germination, & filamentous growth. In the presence of its host insect, *Beauveria* conidiospores germinate on the surface of the cuticle of host and enter the insect's integument through the germinated hyphal tubes where the fungus alters its development morphology to a yeast-like phase and produces hyphal bodies by budding like growth, which circulate in the haemolymph resulting in the host death. The fungal growth [99,100] then reverts back to the typical hyphal form (the saprotrophic stage).

Beauveria bassiana, fungus, is a common pathogen of a range of insects belonging to various gatherings. This fungus often exerts a good degree of natural biological control [101] under humid conditions. In March 2013, genetically modified *Beauveria bassiana* was found in a number of research labs and greenhouses outside of a designated containment area at Lincoln University in Christchurch, New Zealand. The Ministry for Primary Industries investigated. Depending on the strain, medium, and culture parameters, the fungal biomass is increased via vegetative growth.



Figure 1: Growth of *Beauveria bassiana* on PDA

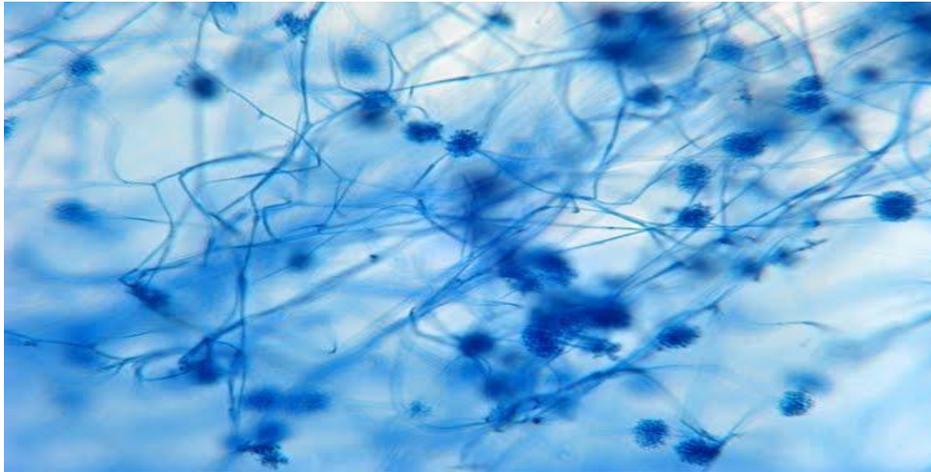


Figure 2: *Beauveria bassiana* under microscope

Mode of Action

The conidiophore forcibly discharges the conidium, which is covered with a mucilaginous sticky substance. When the conidium lands on a moist substrate other than the host, it may produce a secondary conidiophore and secondary conidium, which may produce tertiary conidiophores and conidia [101-104]. This process may continue until the protoplasm is depleted or a suitable host is found. Secondary and tertiary conidia may become resting spores. Secondary conidia (capilliconidia) may be borne on narrow capillary conidiophores. The surface of the capilliconidia has sticky substances, which adhere to the spores to objects with which they come in contact. Upon germination, the conidium produces a germ tube that penetrates the insect cuticle and enters the hemocoel. Inside the hemocoel, the fungus forms protoplasts, hyphal bodies, and hyphae. The protoplasts appear early in infection and have amoeboid movement.

Conclusion

Development of Microbial genetics in coming current years will have a broad spectrum of application, usage and can serve to save a large range of pollution. The new techniques have no side effects but will be more effective than previous techniques for removing several heavy metals from environment. Looking upon the development of Microbiology scientist and researchers need to accelerate in India. In India we should take appropriate steps to develop Microbiology such as Centre of Microbiology & Biotechnology, Research & Training Institute Bhopal, Department of Microbiology & cell biology Indian Institute of Science Bangalore, The Department of Microbiology, Bose Institute, Calcutta are making efforts to develop research and innovation in Microbiology.

REFERENCE

1. Elekwachi CO, Andresen J. Global Use of Bioremediation Technologies for Decontamination of Ecosystems. *J Bioremed Biodeg* 2014;5(225).
2. Abid A, Zaafouri K. Feasibility of a Bioremediation Process Using Biostimulation with Inorganic Nutrient NPK for Hydrocarbon Contaminated Soil in Tunisia. *J Bioremed Biodeg* 2014;5(224).

3. Tandlich R. The “Old-New” Challenges of Water, Sanitation and Bioremediation in Developing Countries. *J Bioremed Biodeg* 2014;5(e152).
4. Bhatt SM, Shilpa, Sidhu M, et al. Scope of In-situ Bioremediation for Polluted Aquifers via Bioaugmentation. *J Bioremed Biodeg* 2014;5(e150).
5. Olawale AM. Bioremediation of Waste Water from an Industrial Effluent System in Nigeria Using *Pseudomonas aeruginosa*: Effectiveness Tested on Albino Rats. *J Pet Environ Biotechnol* 2014;5(167).
6. Morales AR, Paniagua-Michel J. Bioremediation of Hexadecane and Diesel Oil is Enhanced by Photosynthetically Produced Marine Biosurfactants. *J Bioremed Biodeg* 2013;S4(5).
7. Khan F, Sajid M. In Silico Approach for the Bioremediation of Toxic Pollutants. *J Phylogenetics Evol Biol* 2013;4(161).
8. Chauhan A, Kaith B. Bioremediation of Natural Fiber by Graft Copolymerization. *J Chem Eng Process Technol* 2013;S6(2).
9. Makkar RS, DiNovo AA. Enzyme- Mediated Bioremediation of Organophosphates Using Stable Yeast Biocatalysts. *J Bioremed Biodeg* 2013;4(182).
10. Erkekoglu P, BelmaKoçer G. Testicular Dysgenesis Syndrome and Phthalates: Where do we Stand?. *J Genit Syst Disor.* 2015;4(1).
11. Tsompos C, Panoulis C, Toutouzas K, et al. The Effect of the Antioxidant Drug “U-74389g” On Endosalpingeal Edema during Ischemia Reperfusion Injury in Rats. *J Genit Syst Disor.* 2015;4(1).
12. Kumar P, Chhabra S. Rare Presentation of Haematometra and Haematocolpos Presenting as Bleeding Per Vagina. *J Genit Syst Disor.* 2015;4(1).
13. Lima-Silva J, Vieira-Baptista P, Beires J. Vulvar Abrikossoff’s Tumour: Case Report and Review of the Literature. *J Genit Syst Disor.* 2014;4(1).
14. Ventolini G. Vaginal Leptothrix: From Fungi to Lactobacillosis. *J Genit Syst Disor.* 2015;4(1).
15. Mahendru R, Bansal S. Leiomyoma through History: An Overview. *J Genit Syst Disor.* 2015;4(3).
16. Grau Piera S, Aguilo SO, Novell GM, et al. Clinical Manifestation, Diagnosis and Histology of Ovarian Luteoma: Case Report of Female Virilisation and Review of the Literature. *J Genit Syst Disor* 2015;4(4).
17. Goodman A, Joseph N, Bradford LS, et al. Global Health: Role of HPV Testing in Resource Poor Environment. *J Genit Syst Disor.* 2015;4(4).
18. Passarelli V, Gervasi MC, Aquila S. Recent Advances in the Human Male Gamete Molecular Composition in Normal and Varicocele Sperm and Steroid Receptors. *J Genit Syst Disor.* 2016;5(3).
19. Keller NA, Hall J, Sack V, et al. Maternal Congenital Central Hypoventilation Syndrome in Pregnancy: A Case Report. *J Genit Syst Disor.* 2016;5:3.
20. Gupta S, Sinha A. Potential Markers of Endometriosis: Latest Update. *J Genit Syst Disor.* 2016;5(3).
21. Bohbot JM, Druckmann R. Efficacy and Tolerance of a New Ointment in Non-Infectious Vulvitis, Anitis and Balanitis. *J Genit Syst Disor.* 2016;5(3).
22. Ni YY, Huang YW, Cao D, et al. Establishment of a DNA-launched infectious clone for a highly pneumovirulent strain of type 2 porcine reproductIVe and respiratory syndrome virus: identification and in vitro and in vivo characterization of a large spontaneous deletion in the nsp2 region. *Virus Res.* 2011;160(1).

23. Dayao D, Gibson JS, Blackall PJ, et al. Antimicrobial resistance genes in *Actinobacillus pleuropneumoniae*, *Haemophilus parasuis* and *Pasteurella multocida* isolated from Australian pigs. *Aust Vet J.* 2016;94(7).
24. Ward CK, Inzana TJ. Resistance of *Actinobacillus pleuropneumoniae* to bactericidal antibody and complement is mediated by capsular polysaccharide and blocking antibody specific for lipopolysaccharide. *J Immunol.* 1994;153(5).
25. Rioux S, Galarneau C, Harel J, et al. Isolation and characterization of a capsule-deficient mutant of *Actinobacillus pleuropneumoniae* serotype 1. *Microb Pathog.* 2000;28(5):279-89.
26. Bossé JT, Janson H, Sheehan BJ, et al. *Actinobacillus pleuropneumoniae*: pathobiology and pathogenesis of infection. *Microbes Infect.* 2002;4(2):225-35.
27. Jacques M. Role of lipo-oligosaccharides and lipopolysaccharides in bacterial adherence. *Trends Microbiol.* 1996;4(10):408-9.
28. Jacques M. Surface polysaccharides and iron-uptake systems of *Actinobacillus pleuropneumoniae*. *Can J Vet Res.* 2004;68(2):81-5.
29. Jacques M, Paradis SE. Adhesin-receptor interactions in Pasteurellaceae. *FEMS Microbiol Rev.* 1998;22(1):45-59.
30. Osicka R, Procházková K, Sulc M, et al. A novel "clip-and-link" activity of repeat in toxin (RTX) proteins from gram-negative pathogens. Covalent protein cross-linking by an Asp-Lys isopeptide bond upon calcium-dependent processing at an Asp-Pro bond. *J Biol Chem.* 2004;279(24):24944-56.
31. Sirois M, Lemire EG, Levesque RC. Construction of a DNA probe and detection of *Actinobacillus pleuropneumoniae* by using polymerase chain reaction. *J Clin Microbiol.* 1991;29(6):1183-7.
32. Ohshiro K, Kakuta T, Nikaidou N, et al. Molecular cloning and nucleotide sequencing of organophosphorus insecticide hydrolase gene from *Arthrobacter* sp. strain B-5. *J Biosci Bioeng.* 1999;87(4):531-4.
33. Gram T, Ahrens P. Improved diagnostic PCR assay for *Actinobacillus pleuropneumoniae* based on the nucleotide sequence of an outer membrane lipoprotein. *J Clin Microbiol.* 1998;36(2):443-8.
34. Dill KA. The meaning of hydrophobicity. *Science.* 1990;250(4978):297-8.
35. Abioye OP, Adefisan AE, Aransiola SA, et al. Biosorption of Chromium by *Bacillus subtilis* and *Pseudomonas aeruginosa* Isolated from Waste Dump Site. *Expert Opin Environ Biol.* 2015;4(1).
36. Ivanov VB, Alexandrova VV, Usmanov IY, et al. Comparative Evaluation of Migrating Anthropogenic Impurities in Ecosystems of the Middle Ob Region through Bioindication and Chemical Analysis. *Vegetos.* 2016;29(2).
37. Morsi MS, Farrag AA, Elewa AMT, et al. Environmental Impact of Anthropogenic Activities on the Surface Water Resource and Evaluated For Drinking and Domestic Uses around the River Nile, Assiut Governorate: Upper Egypt. *J Hydrogeol Hydrol Eng.* 2016;5(2).
38. Mahmud-Al-Rafat A, Mahbub-E-Sobhani, Taylor-Robinson AW. Understanding the Complex Relationship between the Human Pathogen Hantavirus and its Rodent Reservoirs Underpins a Rational Disease Control Strategy. *J Virol Antivir Res.* 2016;4(4).
39. Morsi MS, Farrag AA, Elewa AMT, et al. Quantitative Analyses of Surface Water and Groundwater Resources around the River Nile, Assiut Governorate, Upper Egypt: Water Quality in Relation to Anthropogenic Activities. *J Hydrogeol Hydrol Eng.* 2015;4(3).
40. Udaya Kumar P, Chandran A, Jose JJ, et al. Nutrient - Characteristics, Stoichiometry and Response Stimulus of Phytoplankton Biomass along the Southwest Coastal Waters of India. *J Mar Biol Oceanogr.* 2014;3(3).

41. Singh JS, Singh DP. Impact of Anthropogenic Disturbances on Methanotrophs Abundance in Dry Tropical Forest Ecosystems, India. *Expert Opin Environ Biol*. 2013;2(3).
42. Thelma J, Asha Devi NK. Evaluation of Probiotics from Mucus Associated Epibiotic Bacteria on Marine Fishes. *J Mar Biol Oceanogr*. 2016;5(3).
43. Sahu PK, Lavanya G, Gupta A, et al. Fluid Bed Dried Microbial Consortium for Enhanced Plant Growth: A Step towards Next Generation Bio Formulation. *Vegetos*. 2016;29(4).
44. Strehlow B, Bakowsky U, Pinnapireddy SR, et al. A Novel Microparticulate Formulation with Allicin In Situ Synthesis. *J Pharm Drug Deliv Res*. 2016;5(1).
45. Shikani AH, Jabra-Rizk MA, Shikani HJ, et al. Rhinotopic Therapy for Refractory Rhinosinusitis: Clinical Effectiveness and Impact on the Epithelial Membrane and Mucosal Biofilms. *J Otol Rhinol*. 2015;4(5).
46. Devi EC, Devi J, Kalita PP, et al. Phytochemical Analysis of *Solanum virginianum* and its Effect on Human Pathogenic Microbes with Special Emphasis on *Salmonella typhi*. *J Forensic Toxicol Pharmacol*. 2016;5(1).
47. Bošnjak M, Alfirevic Z, Alfirevic I, et al. Modelling Kinetics in Intestinal Compartment of Human Body as a Function of Applied Probiotics. *J Food Nutr Disor*. 2015;4(3).
48. Sene G, Thiao M, Mbaye MS, et al. The Linkages between Plant Species Composition and Soil Microbial Communities: What about Symbiotic Microorganisms within Man-Made Tree Plantations? *J Biodivers Manage Forestry*. 2014;3(4).
49. Debs-Louka E, El Zouki J, Dabboussi F. Assessment of the Microbiological Quality and Safety of Common Spices and Herbs Sold in Lebanon. *J Food Nutr Disor*. 2013;2(4).
50. Dimonte S, Babakir-Mina M. Variability and Signatures of Capsid Amino Acid of HIV-1 D-Subtype from Drug-Naïve and ARV-treated Individuals. *J Virol Antivir Res*. 2016;5(1).
51. Mandal S, Mandal MD. Can Bacteria Subsist on Antibiotics? *J Forensic Toxicol Pharmacol*. 2015;4(2).
52. Aslan A. Aquatic Microbiology in a Rapidly Changing World. *Expert Opin Environ Biol*. 2012;1(1).
53. Abioye OP, Adefisan AE, Aransiola SA, et al. Biosorption of Chromium by *Bacillus subtilis* and *Pseudomonas aeruginosa* Isolated from Waste Dump Site. *Expert Opin Environ Biol*. 2015;4(1).
54. Naddeo V, Scannapieco D, Belgiorio V. Membrane Technology in Wastewater Treatments. *J Hydrogeol Hydrol Eng*. 2012;1(1).
55. Thelma J, Asha Devi NK. Evaluation of Probiotics from Mucus Associated Epibiotic Bacteria on Marine Fishes. *J Mar Biol Oceanogr* 2016;5(3).
56. Prinzing R, Misovic A, et al. Ontogeny of Blood Parameters in the Domestic Fowl *Gallus gallus domesticus*: II. Plasma Parameter. *J Vet Sci Med Diagn* 2015;4(5).
57. Prinzing R, Misovic A, et al. Ontogeny of Blood Parameters in the Domestic Fowl *Gallus gallus domesticus*: I. Blood Cells and Haemoglobin. *J Vet Sci Med Diagn* 2015;4(5).
58. Roy SK, Maiti S, et al. Maternal Body-Mass-Index and Socioeconomic Factors Predict Gestational Duration and Birth Weight: A Cross-Sectional Study from India. *Cell Biol: Res Ther* 2015;4(1).
59. Hassanen RA, Morsy AA, et al. Leaf Dust Accumulation and Air Pollution Tolerance Indices of Three Plant Species Exposed to Urban Particulate Matter Pollution from a Fertilizer Factory. *Vegetos* 2016;29(3).
60. Heinrich J, Guo F, et al. Traffic-Related Air Pollution Exposure and Asthma, Hayfever, and Allergic Sensitisation in Birth Cohorts: A Systematic Review and Meta-Analysis. *Geoinfor Geostat: An Overview* 2016;4(4).

61. Chaube R, Pandey AK, et al. Pentachlorophenol-Induced Oocyte Maturation in Catfish *Heteropneustes Fossils*: An In Vitro Study Correlating with Changes in Steroid Profiles. *J Pharm Sci Emerg Drugs* 2016;4(1).
62. Bhupander Kumar, Virendra Kumar V, et al. Human Health Hazard due to Metal Uptake via Fish Consumption from Coastal and Fresh Water Waters in Eastern India Along the Bay of Bengal. *J Mar Biol Oceanogr* 2013;2(3).
63. Feng H, Nwachukwu MA. Should Dispersants be Used to Alleviate the Impact of a Marine Oil Spill? *J Hydrogeol Hydrol Eng* 2012;1(1).
64. Dimonte S, Babakir-Mina M. Variability and Signatures of Capsid Amino Acid of HIV-1 D-Subtype from Drug-Naïve and ARV-treated Individuals. *J Virol Antivir Res* 2016;5(1).
65. Mandal S, Mandal MD. Can Bacteria Subsist on Antibiotics? *J Forensic Toxicol Pharmacol.* 2015;4(2).
66. Aslan A. Aquatic Microbiology in a Rapidly Changing World. *Expert Opin Environ Biol* 2012;1(1).
67. Ukpaka CP. Modelling the Methodology for Crude Oil Bioremediation Decision Tree for an Integrated Environmental Management System. *J Chem Eng Process Technol* 2017;8(325).
68. Ritu A, Anjali C, et al. Biopesticidal Formulation of *Beauveria Bassiana* Effective against Larvae of *Helicoverpa Armigera*. *J Biofertil Biopestici* 2012;3(120).
69. Ukpaka CP, Kingdom U. Effect of Physicochemical Parameters on Screening Characteristics of Suspension in Bioremediation Sampling. *J Anal Bioanal Tech* 2017;8(345).
70. Meliani A, Bensoltane A. Biofilm-Mediated Heavy Metals Bioremediation in PGPR *Pseudomonas*. *J Bioremediat Biodegrad* 2016;7(370).
71. Aulwar U, Awasthi RS. Production of Biosurfactant and their Role in Bioremediation. *J Ecosys Ecograph* 2016;6(202).
72. Pisciotto JM, Dolceamore JJ. Bioelectrochemical and Conventional Bioremediation of Environmental Pollutants. *J Microb Biochem Technol* 2016;8.
73. Akpomie Olubunmi O, Ejechi Bernard O. Bioremediation of Soil Contaminated with Tannery Effluent by Combined Treatment with Cow Dung and Microorganisms Isolated from Tannery Effluent. *J Bioremed Biodeg* 2016;7(354).
74. Satyapal GK, Rani S, et al. Potential Role of Arsenic Resistant Bacteria in Bioremediation: Current Status and Future Prospects. *J Microb Biochem Technol* 2016;8(256).
75. Azoddein AABM, Ahmad MM, et al. A Bioremediation Approach to Mercury Removal in a Shake Flask Culture Using *Pseudomonas putida* (ATCC 49128). *J Anal Bioanal Tech* 2016;7(312).
76. Ramakrishnan B. Bioremediation with Simultaneous Recovery and Reuse of Resources. *J Bioremed Biodeg* 2016;7(e172).
77. Uqab B, Mudasar S, et al. Review on Bioremediation of Pesticides. *J Bioremed Biodeg* 2016;7(343).
78. Xenia ME, Refugio RV. Microorganisms Metabolism during Bioremediation of Oil Contaminated Soils. *J Bioremed Biodeg* 2016;7(340).
79. Kiraye M, John W, et al. Bioremediation Rate of Total Petroleum Hydrocarbons from Contaminated Water by *Pseudomonas aeruginosa* Case Study: Lake Albert, Uganda. *J Bioremed Biodeg* 2016;7(335).
80. Uqab B, Mudasar S, et al. Bioremediation: A Management Tool. *J Bioremed Biodeg* 2016;7(331).
81. Jesus HE, Peixoto RS, et al. Bioremediation in Antarctic Soils. *J Pet Environ Biotechnol* 2015;6(248).

82. Obreque-Contreras J, Pérez-Flores D, et al. Acid Mine Drainage in Chile: An Opportunity to Apply Bioremediation Technology. *Hydrol Current Res* 2015;6(215).
83. Luisa WM, Letícia T, et al. Culture-Independent Analysis of Bacterial Diversity during Bioremediation of Soil Contaminated with a Diesel-Biodiesel Blend (B10)S. *J Bioremed Biodeg* 2015;6(318).
84. Caruso G. Plastic Degrading Microorganisms as a Tool for Bioremediation of Plastic Contamination in Aquatic Environments. *J Pollut Eff Cont* 2015;3(e112).
85. Hamid B, Kaushik G, et al. Isolation and Development of Efficient Bacterial Consortia for Bioremediation of Textile Dye Effluent. *J Pollut Eff Cont* 2015;3:142.
86. Sadiq S, Inam HM, et al. Bioremediation Potential of White Rot Fungi, *Pleurotus* Spp against Organochlorines. *J Bioremed Biodeg* 2015;6(308).
87. Nandi R, Mukherjee K, et al. Surfactant Assistant Enhancement of Bioremediation Rate for Hexavalent Chromium by Water Algae. *Biochem Physiol* 2015;4(173).
88. Soumya GN, Manickavasagam N, et al. Optimization of pH, Retention Time, Biomass Dosage in Beads and Beads Density on Textile Dye Effluent Bioremediation using Seagrass, *Cymodocea rotundata* Beads. *J Bioremed Biodeg* 2015;6(295).
89. Mukherjee P. Bioremediation with the Help of Analytical Tool- Biosensors. *J Bioremed Biodeg* 2015;6(292).
90. Pawar RM. The Effect of Soil pH on Bioremediation of Polycyclic Aromatic Hydrocarbons (PAHS). *J Bioremed Biodeg* 2015;6(291).
91. Iturbe R, López J. Bioremediation for a Soil Contaminated with Hydrocarbons. *J Pet Environ Biotechnol* 2015;6(208).
92. Kumar R, Chauhan A, et al. Bioremediation of Polluted Soil obtained from Tarai Bhavan Region of Utrakhand, India. *J Bioremed Biodeg* 2015;6(276).
93. Kulkarni AG, Kaliwal BB. Bioremediation of Methomyl by Soil Isolate - *Pseudomonas aeruginosa*. *J Bioremed Biodeg* 2015;6(281).
94. Paniagua-Michel J, Rosales A. Marine Bioremediation- A Sustainable Biotechnology of Petroleum Hydrocarbons Biodegradation in Coastal and Marine Environments. *J Bioremed Biodeg* 2015;6(273).
95. Ofoegbu RU, Momoh YOL, et al. Bioremediation of Crude Oil Contaminated Soil Using Organic and Inorganic Fertilizers. *J Pet Environ Biotechnol* 2015;6(198).
96. Shah MP. Environmental Bioremediation: A Low Cost Nature's Natural Biotechnology for Environmental Clean-up. *J Pet Environ Biotechnol* 2014;5(191).
97. Saraswat S. Patent Analysis on Bioremediation of Environmental Pollutants. *J Bioremed Biodeg* 2014;5(251).
98. Garima T, Singh SP. Application of Bioremediation on Solid Waste Management: A Review. *J Bioremed Biodeg* 2014;5(248).
99. Gularte HF, Diaz ME, et al. Effect of Temperature and Salts on Phenol Bio-Availability in Polluted-Sandy- Soils: A Practical Biotechnological Approach before Microbial Bioremediation. *J Bioremed Biodeg* 2014;5(240).
100. Sabale SR. Contamination and Need of Bioremediation of Pesticide Residues in Fresh Water Aquifers. *J Bioremed Biodeg* 2014;5(e158).
101. El-Bestawy E, Sabir J, et al. Comparison among the Efficiency of Different Bioremediation Technologies of Atrazine-Contaminated Soils. *J Bioremed Biodeg* 2015;5(237).

- 102.Hasan R, Zhang B, et al. Bioremediation of Swine Wastewater and Biofuel Potential by using *Chlorella vulgaris*, *Chlamydomonas reinhardtii*, and *Chlamydomonas debaryana*. *J Pet Environ Biotechnol* 2014;5(175).
- 103.Malik A. Hazardous Cocktails: Challenges and Innovations in Bioremediation. *J Bioremed Biodeg* 2014;5(e156).
- 104.Kulshreshtha S, Sharma K. Perspectives of Bioremediation through Mushroom Cultivation. *J Bioremed Biodeg* 2014;5(e154).