**Novel Approach On Bioremediation by Actinobacteria : A Review**

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**Abstract**

A significant environmental problem that has created serious difficulties for the agricultural ecology is toxic pollution. Among the most harmful environmental pollutants are heavy metals and insecticides. Bioremediation techniques include Bioaugmentation , Bioinjection , and Phytoremediation. It eliminates and catabolizes environmental contaminants using natural or artificial plants and soil bacteria. Many vital ecological activities are fulfilled by Actinobacteria in nature, including breaking down and recycling complex polymers and generating bioactive chemicals. As a result, biotechnologists are intrigued by the prospect of cleaning up contamination with Actinobacteria. This can be done using the green method of Bioremediation, in which certain microorganisms are introduced into contaminated areas to increase their degradative ability. Thus, Actinobacteria make excellent bioremediation candidates, which is important as more contaminants are released into the environment. This article discusses ways to mitigate the effects of heavy metals and pesticides on agricultural ecosystems by using Actinobacteria as a Bioremediation agent.

**Keywords:** Actinobacteria, Bioremediation, Pesticides, Heavy metals, Environmental pollution

**Introduction**

In the past two decades, environmentally friendly methods for decontaminating polluted environments have developed that make use of a wide variety of microbial species. The term for this kind of process is bioremediation, and it is typically thought to be less intrusive and more beneficial to soil functioning than traditional physicochemical treatments [1, 2]. Importance of bioremediation as a sustainable technology examining the significant discharge of human-made toxins into the environment[3].

Pesticides are chemicals used for pest control and are perhaps the most extensively dispersed environmental pollutants [4]. The dumping of outmoded pesticide stocks has also resulted in the long-term contamination of several locations with extremely high concentrations of chemicals of this sort. According to official reports, organochlorine (OC) insecticides have been discovered in Brazil, Argentina, Chile, Poland, Spain, the Netherlands, China, Canada, the United States, and India. [5, 6]. Because unlawful polluted storage facilities are still present, these reports understate the true problem More than 30 tons of OC pesticides, including lindane, chlordane, methoxychlor, aldrin, and DDT, and heavy metals, including Cr(VI), Cu(II), and Cd(II), were illegally dumped southeast of Santiago del Estero, Argentina [7, 8]. Pollution from farming is thought to be diffuse because the compounds are spread out over large areas and are in very low concentrations. Pesticides have been found in many places around the world, including the air, water, soil, food, milk, fish, and even human blood and fat tissue [9, 10].

Heavy metals are naturally occurring components of soil; however, certain heavy metals are essential for the health of animals and plants because of their role as cofactors in a wide variety of enzymes[11]. However, industrial development has exacerbated biosphere contamination by heavy metals, which become very poisonous at large doses. Heavy metal toxicity is largely caused by the discharge of heavy metals from a variety of different industries all over the world[12]. Heavy metals including copper, chromium, lead, zinc, and cadmium often found in effluents and waste water discharged by industry can have serious effects on the environment and human health [13, 14]. Heavy metals are extensively distributed in the biosphere and are spread in the air, soil, and water, and their accumulation in living different types of tissues, the food chain, and the food chain leads to a significant health hazard in people [15]. It was well known that long-term exposure to heavy metals led to slow growth in babies, the start of different types of cancer, and damage to the liver and kidneys [16]and exposition to a high quantity of heavy metals that results in mortality. In recent years, there has been a rapid rise in the risk of heavy metals contamination in the environment, particularly in the agricultural sector. This is due to accumulation in the soil and plant absorption, both of which have taken place in recent years[17]. Heavy metals are required for multiple organs in both plants and humans; however, when their concentration exceeds the prescribed level, they become toxic. Numerous scientific investigations have led researchers to the conclusion that agriculture, mining, agrochemical production, and industry are the primary contributors of heavy metals[18, 19]. Heavy metal accumulation is defined as a buildup of components in the environment. Heavy metal ions transferred from the soil must come into touch with plant roots. They have the potential to stabilize and link contaminants in the soil, decreasing their bioavailability [20, 21]. The mechanisms by which heavy metals are transferred to plants include (I) phytoextraction, which is a sub process of phytoremediation in which plants eliminate hazardous components from contaminated soil, (ii) Phytostabilization, which is the immobilisation and reduction of the mobility of heavy metals in the soil, and (iii) Rhizofiltration, which is a form of phytoremediation that makes use of plant roots to absorb the various toxic substances.In addition to causing damage to plants, the transfer of these metals down the food chain is detrimental to human health [22, 23]. Actinobacteria is recognised as one of the most significant and diverse phyla within the domain Bacteria due to its prominent branching position in the tree representing the 16S rRNA gene. Actinobacteria are categorised as either Gram-positive or Gram-variable aerobes. They have a cell wall that is rigid and is composed of muramic acid.The majorities are chemo-organotrophs, and free-living members of the phylum are commonly recognized as possessing a high G+C content [24]. Actinobacteria have garnered interest as potential bioremediation candidates for several environmentally polluted compartments containing recalcitrant inorganic and organic contaminants. Extremophile Acidimicrobium ferrooxidans can thrive at a pH of 1.8 and a temperature of 45°C.. The collection strain *Acidimicrobium ferrooxidans* DSM 10331T was tolerant up to Zn(II) 33×103 mg L -1, whereas *A. ferrooxidans* N39 30×103 mg L -1, isolated from a spent copper sulphide heap, was tolerant to higher concentrations of several metals, including Zn(II), demonstrating its robust adaptation to the hostile environment [25]. Microorganisms belonging to the genus Streptomyces, as well as those belonging to the genera Arthobacter and Rhodococcus, have received a significant amount of attention as a potential biotechnological method for cleaning up polluted environments[26]. *Streptomyces* strains, in addition to their metabolic variety, may be well suited for soil inoculation due to their mycelial growth habit, relatively quick growth rates, colonisation of semi-selective substrates, and ability to be genetically altered[27]. *Streptomyces* strains may thrive on and breakdown a variety of pesticides, including pyrethroids, atrazine, and diuron, among others[28]. According to the bibliographies that have been published in the past two decades, the genera Arthrobacter, Rhodococcus, Streptomyces, Frankia, Janibacter, Kokuria, Mycobacterium, Nocardia, and Pseudonocardia are the most representative pesticide-degrading actinobacteria. These bacteria are capable of cultivating and degrading a wide variety of pesticide chemical families, including OC, CB, OP, pyrethroids, ureas, and chloroacetanilides, among others[26].

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| --- | --- | --- | --- |
| **Metal and *Streptomyces*  strain** |  **Isolation sample** | **Mechanism** | **Reference** |
| As(V) VITDDK3 | Marine soil samples collected at the Ennore saltpan | ND | [29] |
| B(III) *Streptomyces* sp. | B-contaminated soils, Salta, Argentina | ND | [30] |
| Cd(II) *S. rimosus* | Biomass produced during oxytetracyclin | Biosorption | [31] |
| Cd(II) *S. zinciresistens* | Zincecopper mine, Shaanxi province, Northwestern China | Biosorption/Bioaccumulation | [32] |
| Cr(III) VITSVK9 | Marine sediment, Bay of Bengal, India | Biosorption | [33] |
| Cr(VI) *S. griseus* NCIM 2020 | National Collection of IndustrialMicroorganisms, Pune, India | Reduction | [34] |
| Cr(VI)*S.thermocarboxydus* NH50 | Soil contaminated by leaking drums of metal finishing effluents, Lyon, France | Reduction by agents present in the supertant | [35] |
| Cu(II) *Streptomyces* sp. | Copper filter plant, Tucuman, Argentina | ND | [36] |
| Cu(II) *S. flavovirens* ON3 | Soil exposed to heavy traffic emissions, Brno, Czech | Biosorption | [37] |
| Hg(II) *S. coelicolor* M130 | Culture collection | Enzymatic reduction | [38] |
| Ni(II) *S. aureofaciens* NR-3 | Riparian sediments contaminated with high levels of Ni and U, Steed Pond, USA | Ni-influx and Ni-efflux transporters would be present to maintain homeostasis | [39] |
| Zn(II) *S. rimosus* | Biomass produced by an antibiotic production and collected after fermentation | Biosorption | [40] |
| Pb(II) *S. viridochromogenes* | ND | Biosorption | [41] |
|  **Table 1** *Streptomyces* strains beneficial in heavy metal bioremediation |  |

|  |  |  |  |
| --- | --- | --- | --- |
| **Microorganism**  | **Pesticide** |  **Isolation sample** |  **Reference** |
| *Arthrobactersp.*strainAK-YN10 | S-triazine (atrazine) | Agricultural ﬁeld repeatedly treated with atrazine in sugarcane cultivation, India | [42] |
| *Arthrobacter sp*. BS1, BS2 and SED1 | Urea (diuron) | Soil from the interface between a vineyard and the Morcille River, Franc | [43] |
| *Rhodococcus* sp*.* BCH2 | S-triazine (atrazine) | Long-term atrazine-treated grape farm soil, India | [44] |
| *Streptomyces* sp. M7 | Organochlorine (lindane) | Wastewater sediment from a copper ﬁlter plant, Argentina | [45] |
| *Streptomyces* sp. AC1-6 and ISP4 | Organophosphorus (diazinon) | Soil exposed to continuous applications of chlorpyrifos, Chile | [46] |
| *Janibacter* sp. AS2 | Pentachlorophenol | Sediments from arid and saline ecosystems, Tunisia | [47] |
| *Gordonia* sp JAAS1 | Organophosphorus (chlorpyrifos) | Soil from a paddy ﬁeld exposed to continuous applications of chlorpyrifos, India | [48] |

 **Table 2** Characteristics of the major pesticide-degrading actinobacteria genera

**2. Pesticide and heavy metal sources and distribution**

**1. Pesticides**

Pesticide residues from a variety of industries and agricultural practises have been observed; these residues contaminate river ecosystems, including sediments and aquatic biota, and harm humans through their consumption of food and water[49]. Subsurface runoff from agricultural fields frequently introduces a variety of fertilisers and pesticides into nearby rivers[50]. Pesticide residues in groundwater and drinking water have been reported by numerous scientists over the past five years. Because of their solubility in water, adsorption by soil particles, and persistence, pesticides move through soil compartments at different rates[51]. The amount of organic matter that is present in an area has a significant impact on how long pesticides remain in the soil and sediments. Organic matter offers a variety of binding sites for organic pollutants, particularly hydrophobic ones[52]. It is largely due to organic matter that the retention of HCH isomers differs between soil types. In general, when soil components hold on to contaminants, bioavailability goes down and degradation is slowed[53]. A number of pesticides can evaporate from the soil or foliage and travel long distances. This explains the presence of pesticide traces in pristine areas, which suggests that the atmospheric redistribution rather than direct application is responsible for their occurrence. After it was determined by the Global Monitoring Plan of the Stockholm Convention that air is the primary route for the long-distance transport of pesticides all over the world, Spain started monitoring persistent organic pollutants (POPs) in the air in the year 2008[54].

Passive air samplers were placed in seven remote points and four urban Spanish locations to assess DDT and hexachlorobenzene (HCB) levels. When urban and remote locations were evaluated together, the results revealed that HCB was the major pollutant, followed in decreasing order by DDTs [55]. Statistically, urban areas had significantly higher concentrations of all studied families with the exception of HCB, indicating that human activities may be source of DDTs [56].

**2. Heavy Metals**

Heavy metals are found naturally and anthropogenically in soil, water, air, and living organisms [57]. Anthropogenic sources produce pollution that continues to increase over time, whereas natural sources are usually seasonal, weather-dependent, and do not produce pollution [58, 59]. Heavy metals come from things made by people, like factories, farms, and wastewater. Heavy metals and pollution in the ecosystem are made worse by these sources. For example, smelting these metals releases Cu, Zn, and Pb [60] the combustion of fossil fuels produces Hg, and car exhaust contributes to the release of Pb [61]. Some heavy metals are necessary for the continued existence of all known forms of life. This is due to the fact that they are able to perform multiple functions within biological systems. Many others, on the other hand, have no known biological role. Cells have homeostatic mechanisms that regulate heavy metal concentrations and reduce the harmful consequences of high levels. The absorbed dose, the mode of exposure, and the length of time that an individual is exposed all play a role in determining the toxicity of heavy metals. It is possible, for instance, to become poisoned by certain heavy metals by ingesting them through drinking water. This is the situation with lead poisoning, which can induce loss of appetite, hypertension, renal failure, weariness, arthritis, hallucinations, and vertigo in people who are exposed to it [62-64]. Mercury is one of the most dangerous heavy metals, and it can react with other elements to generate organic and inorganic mercury. Mercury is released into the environment by a number of different industries, and it is frequently found in larger amounts in most marine organisms as the trophic level of the organism increases[65, 66].

 Fig.1 Different Natural sources of heavy metal pollution

 Fig.2 Diverse human-made sources of heavy metal pollution

There are two major sources of heavy metal pollution 1.Natural sources and 2. Agricultural sources where 1.Natural sources: including the formation of sedimentary rocks and volcanic eruptions, soil, and the weathering of rock surfaces. Igneous and sedimentary rocks are the two types of rocks that are found most frequently[67, 68] It is possible to determine the concentration of heavy metals based on the type of rock and the conditions of the ecosystem in the surrounding area. In addition to river sediments, soil formation is regarded as one of the primary causes of heavy metal accumulation and 2.Agricultural sources : Typically, agro ecosystems are impacted by the numerous types of pollutants, including agricultural pollutants, which are known as biotic and abiotic byproducts of farming practices [69]. Agro ecosystems can be contaminated or degraded as a result of these pollutants. Heavy metals can be found in agricultural settings most frequently through the use of fertilizers, pesticides, and sewage sludge. The use of fertilizers leads to the accumulation of heavy metals in the soil and plants used in agricultural production. Fertilizers deliver a diverse spectrum of nutrients to the soil, which, in turn, encourages healthy plant growth and contributes to an increase in the organic matter content of the soil[70]. As a result, fertilizers increase the fertility of the soil. An organic fertilizer is one that is derived from organic matter, while an inorganic fertilizer is one that is synthesized. After the anaerobic digestion (AD) process, ammonium fertilizers (sulphate and nitrate) are produced as organic or bio fertilizers. Chemically manufactured/synthetic fertilizers, also known as inorganic fertilizers, are a mixture of inorganic and chemical substances. For example, organic and inorganic fertilizers, which are responsible for releasing heavy metals into our soil [71]. Phosphorus is put to extensive use in the production of fertilizer; however, it is also a major contributor to the buildup of heavy metals in soil. It has been demonstrated that fertilizers that contain phosphorus that is insoluble in water can produce phosphate rocks. Phosphate rocks are essential to the ability of the soil to precipitate metal phosphates and maintain their immobilization.. The accumulation of heavy metals in agricultural soils as a consequence of prolonged and excessive use of fertilizers leads to a reduction in soil fertility, which in turn leads to a reduction in plant growth and productivity. [72, 73]. After heavy metals have contaminated the soil, it is extremely difficult to restore its natural environment.

**3. Effect of Pesticides and Heavy Metals Toxicity on Agricultural soil and Plants**

**1. Heavy Metals Toxicity**

In the rhizosphere, where metalliferous minerals and substances interact with root exudates, heavy metals first affect plants. Carbonate formations on plant roots indicate mineral dissolution and oxidation in the rhizosphere. Metal concentrations have been found to be higher in rhizosphere solutions as a result of these processes. Due to the wide range of physiological and biochemical deficiencies that can result from a high concentration of Pb, the interactions between Cu and Zn, which influence each other, can affect the bioavailability of nutrients[74, 75]. The action pathway and mechanism of heavy metals, beginning with soil accumulation and progressing to different plant organs. By increasing intracellular levels of reactive oxygen species (ROS), heavy metals produce free radicals that induce oxidative stress and damage to biological molecules (e.g., proteins, nucleic acids, lipids, and enzymes)[76-78]. The problem with all of these biological molecules causes a lot of problems in the plant's body, such as damage to DNA and cells and the stopping of enzyme activities, which could lead to the death of the whole plant.

**2. Pesticides Toxicity**

When pesticides are used in large amounts and without control on different types of crops, they hurt beneficial organisms. Also, these effects throw off the balance of biodiversity in the whole ecological system. Many pesticides, their byproducts, and metabolites are studied to see if they are somewhat safe for beneficial organisms, especially beneficial insects, to come into direct contact with when they eat plant tissue [79, 80]. The transmission of systemic pesticides through the plant's vascular system contaminates floral and extra floral nectar, resulting in high mortality rates for honeybees and nectar-feeding parasitoids[81, 82]. Endrin, hexachloro benzene dioxy pyrimidine, and other pesticides with chemical structure similar to chlordane can persist in the environment for decades without degrading [83]. In addition, persistent pesticide residues can bio accumulates and reach a bio concentration greater than 70,000 times the initial concentration. Pesticide mechanistic pathway beginning with application and ending with photo degradation, absorption by plant parts, or sorption at the soil level. Once in the soil, pesticides go through several biodegradation processes, including chemical decomposition and biological degradation. pesticide residues and degradation by-products are taken up by roots via xylem to plant parts, causing some negative effects on soil and plant. Overproduction of ROS, oxidative stress, DNA damage, photosynthetic blockage, necrosis, chlorosis, leaf twisting, and plant death are some of these effects[84, 85].

**4. Bioremediation: a solution to the heavy metals and pesticide pollution problem**

Environmental biotechnology is typically defined as "the use of living organisms to remove pollutants from soil, water, and wastewater[86]. In general, bioremediation can be defined as "the use of naturally occurring organisms to convert hazardous substances into less toxic substances". According to ancient records, the Romans were the first to use bioremediation to treat their waste water. Since 1972, however, bioremediation has been used extensively to clean up polluted systems [87]. The bioremediation of hazardous organic compounds is, in general, regarded as a less contentious practice than the bioremediation of heavy metals[88]. This is due to the fact that an organic compound can be completely degraded to carbon dioxide and water via the mineralization process. In some instances, however, microorganisms may fail to complete mineralization and produce intermediates that are more toxic than the original compound. This can be resolved through additional bio treatments[11, 89]. In order to meet the fundamental requirements of the world's population, there must be a rise in both the rate of food production and the amount of activity in the industrial sector. One of the consequences of these human-caused activities is that areas all over the world have been found to be contaminated with toxic organic and inorganic compounds. This type of concurrent contamination is known as co-contamination[90] as represents the true difficulty that grey biotechnology faces at the moment. The removal of organic compounds and heavy metals through bioremediation has been demonstrated to be effective, despite the fact that, for the time being, each process is typically carried out separately. Unquestionably, a multifunctional biological process is necessary in order to carry out bioremediation on sites that are co-contaminated. In this context, bacteria that belong to the phylum actinobacteria have a significant amount of potential because it has been demonstrated that they are efficient tools for the bioremediation of pollutants such as pesticides and heavy metals[91]. Because of their potential to bio remediate soils that have been contaminated with multiple pollutants, members of the phylum actinobacteria are currently the subject of research.

**5. Actinobacteria utilizing diverse bioremediation strategies**

Actinobacteria use different ways to clean up waste such as Cell immobilization,Use of plant-microbe partnerships and Use of microbial produced surface-active compounds.

**1. Cell immobilization**

Cell immobilisation is defined as the physical confinement of viable microbial cells to a certain defined space in order to limit their free migration, while maintaining the catalytic activities and enhancing both the biological and physical stabilities of the cells. This is done in order to immobilize the cells without affecting their ability to function normally. Cell encapsulation is another name for the process known as cell immobilization[92]. When compared to conventional suspension systems, this method has several advantages, including the retention of higher concentrations of microorganisms in the reactor, easier solid-liquid separation, high metabolic activity, and higher cell viability. In addition, the technique is simpler to implement [93]. Additionally, the immobilization matrix has the capability of overcoming physicochemical obstacles, such as temperature, pH, and toxic substances; the latter of these is particularly intriguing for its application in bioremediation processes [94]. The immobilization of microbial cells for the purpose of bioremediation led to improved performance, increased production of derivative enzymes, increased tolerance to high concentrations of toxic compounds, elimination of the need to wash the cells, and an extension of the amount of time needed for biochemical or biotransformation reactions, according to the findings of a number of studies. Immobilization of microbial cells was done for the purpose of bioremediation[95]. When microbial cells are used, the efficiency of the degradation process as well as the operational stability are both improved. The choice of support plays a significant role in the immobilization of cells. The remediation of polluted areas necessitates the possession of a number of attributes, including a low cost price, non-biodegradability, non-toxicity, and non-pollutivity, as well as mechanical and chemical stability, high diffusivity, minimal attachment to other organisms, and a high degree of mechanical and chemical stability[96]. The encapsulation of actinobacteria has been shown to be effective in the mineralization of various pollutants, including pesticides, among other things. *Rhodococcus erythropolis* NI86/21, which was encapsulated on alginate beads, can be used to reduce atrazine concentrations in soil as well as liquid medium[97]. Adding bentonite and skimmed milk to the beads' formulation resulted in faster cell release and longer cell survival, respectively. Pesticide removal and actinobacteria immobilization also provided good results for metal bioremediation, providing higher metal resistance and enhanced metal accumulating ability[98]. In this particular scenario, a chromate-reducing bacterium known as *Microbacterium liquefaciens* MP30 was successfully entrapped in polyvinyl alcohol (PVA)-alginate beads, which proved to be the most appropriate support for cell immobilization and chromate reduction. In addition, the removal of chromate from a solution containing 2.6 mg L-1 was maintained at 90-95 percent over a period of 20 days without any signs of bead breakdown; however, the immobilization techniques had very little impact on the biological activity [99, 100]. In contrast, the best immobilization matrices for *Microbacterium* sp. NCIMB 13776 for the reduction of Cr (VI) were found to be agar and agarose [101]. Therefore, it is possible to draw the conclusion that the microorganism that was utilized may have a greater effect on the removal of the metal than the immobilization method did. According to a number of reports, the utilisation of immobilised actinobacteria as a method for the bioremediation of polluted sites is a promising alternative for the bioremediation of polluted sites, being efficiently reused for the removal of metals as well as pesticides. These reports all confirm that the utilisation of immobilised actinobacteria as a method for bioremediation is a viable option. The efficiency of the process can be affected by a variety of factors, including the pollutants that are present, the longevity and reusability of the immobilised cells, and a number of other factors. Nevertheless, a significant amount of research is required to determine the most appropriate support.

**2. Use of plant-microbe partnerships**

In recent years, there has been a growing interest in the impact that microorganisms have on the growth of plants, the bioavailability of contaminants, and their degradation. The influence of plant-associated microorganisms on the effectiveness of phytoremediation is the subject of an ever-increasing number of research studies. It has been suggested that phytoremediation techniques, which are based on the interactions between plants and microorganisms, are methods for decontaminating polluted soils that are both cost-effective and friendly to the environment[102, 103]. The release of plant root exudates (REs), which contain enzymes, amino acids, carbohydrate, low-molecular-mass carboxylic acids, and phenolic compounds, causes an increase in microbial activity, which is attributed to the rhizosphere effect [104]. According to the findings of a number of authors, endophytic bacteria play a role in the biodegradation of toxic compounds, and the plant endophyte association has the potential to be utilised in the cleanup of polluted systems[105]. In addition, the degradation of atrazine was shown to occur when contaminated soil microorganisms were inoculated with arthrobacter sp. DNS10 in the presence of the plant Pennisetum. The authors demonstrated the efficacy of the plant-arthrobacter interactions, which resulted in a 98% reduction in atrazine levels when compared with the effects of a single strain and a single plant. This reduction was compared to the effects of a single strain and a single plant[106, 107]. The majority of research on trace element plant-microbe interactions has been conducted within the framework of phytoremediation. It has been postulated that the microorganisms that are present in the soil, and in particular the bacteria that are active in the rhizosphere, could assist plants in more effectively mobilising and absorbing metals. Quite a few actinobacteria behave in this manner due to the fact that members of this phylum are dispersed in the rizosphere in a variety of different ways. The rizosphere is home to an abundance of secondary metabolite producers. This is typically the result of the production of substances that promote plant growth, such as indole acetic acid, or the production of substances that bind or chelate metals, such as siderophores. Both of these processes are referred to as chelation[108]. In this study, the bacteria that were obtained were, for the most part, resistant to both Cr and Co; however, other tolerance combinations were also found, which indicates that heavy metal resistance evolved independently on multiple occasions[109]. The inherent weaknesses associated with the application of isolated elements can be addressed by developing phytoremediation systems where microorganisms-primarily actinobacteria-interact with plants.

**3. Use of microbial produced surface-active compounds**

The term "bioremediation" refers to the process of removing or neutralising contaminants through the utilisation of biological agents such as plants and microorganisms, in addition to products that are derived from them[110]. Because the producer microorganisms do not need to be able to grow and survive in contaminated environments, the use of microbial products rather than whole cells for environmental remediation could have undeniable advantages. There is a wide variety of surface-active compounds (SACs) that can be found among the microbial products that have the potential to be used in bioremediation technologies. These microbial products can be found in a variety of environments. Low-molecular-weight SACs, also known as bio surfactants (lipopeptide, glycolipids, and phospholipids), reduce the surface tension at the air-water interface. High-molecular-weight SACs, also known as bio emulsifiers (polysaccharides, lipopolysaccharides, proteins, lipoproteins, and complex mixtures of these compounds), reduce the surface tension at the air-water interface[111, 112]. Although it is not uncommon for bio surfactants to possess emulsifying properties, it is not always the case that bio emulsifiers will result in a reduction in surface tension. The demand for surface-active compounds of biological origin as natural alternatives to their counterparts produced synthetically is currently at an all-time high. This is as a result of the fact that surface-active compounds that originate from biological sources have lower levels of toxicity and higher biodegradability than their counterparts that are produced synthetically[113]. These proteins are distinguished by a number of characteristics, one of which is their high stability in harsh conditions of pH, temperature, and salinity. These characteristics give these proteins a wider range of potential applications in a number of different biotechnological fields. In the field of bioremediation, it is possible to encourage in-situ microbial production of SACs in order to boost the bioavailability of organic and inorganic pollutants. This can be accomplished by increasing the temperature of the environment[114]. In the absence of producer microorganisms in the washing process, a more pragmatic approach would be to produce these biomolecules through microbial culture, isolate them, and use them in soil washing technologies. Surface-active molecules can form complexes with pollutants attached to the soil matrix, allowing them to desorb into the aqueous phase. The hydrophobic pollutants, such as pesticides, are stabilized inside the micelles of bio-surfactants once they reach the aqueous phase, which improves their solubility and removal during the washing process[115, 116]. Inorganic pollutants like heavy metals, for example, can be removed from soil by forming micelles with surface-active compounds (SACs). In the last case, however, SAC polar groups can bind, mobilize, and stabilize micelle metals. Numerous actinobacteria capable of producing SACs have been isolated, and subsequent analysis has revealed that they belong to a wide variety of genera. The marine actinobacterium *Nocardiopsis* sp. B4, which was isolated from the western coast of India, was cultivated on a variety of carbon and nitrogen sources. The researchers found that olive oil and ammonium chloride, combined at a C/N ratio of 2:1, resulted in the highest level of production [117]. When grown in solid state culture, the marine sponge-isolated *Brachybacterium paraconglomeratum* MSA21 strain is notable for its ability to produce bio surfactants by utilising both industrial and agro-industrial wastes.[118] , this discovery could be crucial for promoting the large-scale, cost-effective production of microbial SACs. Consequently, the selection of microorganisms capable of growing and producing surfactant/emulsifier molecules from inexpensive raw materials is one of the most alluring strategies for promoting sustainable production [119].

**6. Conclusion**

Environmental pollution is a growing global threat to human health and wellbeing.Biological remediation, which employs living microorganisms, is gaining popularity and is a viable alternative to other hazardous techniques. Actinobacteria can bioremediate oil, rubber, plastics, pesticides, and heavy metals due to their physiological and metabolic versatility.In the past 15 years, significant progress has been made in the utilisation of Actinobacteria for waste elimination. Bio-augmentation, bio-stimulation, cell immobilisation, phytoremediation, biosurfactant production, and the use of defined mixed cultures were developed to enhance Actinobacteria's bioremediation capabilities.

**7. Future prospects**

Due to the constant development of industrial operations, pollutants spread worldwide due to insufficient monitoring of their detrimental environmental consequences. This led to studies on improving contaminated areas. Actinobacteria Bioaugmentation is a green way to rehabilitate the environment. Actinobacteria can metabolise toxins in polluted soils for growth. Actinobacteria may degrade pesticides and remove heavy metals, highlighting their potential as Bioaugmentation techniques[120, 121].

**Declarations**

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**Disclosure statement**

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