Application of green bioremediation technology for soil, water and air remediation

Arti Bijalwan¹ and Vandana Bijalwan²

¹Dunparsi Medical College, Dehradun 248001, Uttarakhand, India
²National Agri-Food Biotechnology Institute, Industrial Area, Mohali, Punjab 160071, India

Abstract

Pollution, a serious environmental problem has been attaining the considerable public awareness over the last decades. Contaminated water streams and landfills represent a technical challenge. New and green technologies are needed to remove innumerable waste especially those which are toxic. Bioremediation is an green technology which is widely used to reduce the toxic pollutants from the environment, with this technology utilization of plants and other biological entities (microbes and enzymes) to cleanup pollutants (metal and organic) from the environment is done which is not only offering eco-friendly approach but are also cost effective. Waste generation is one of the most visible and biggest problems that affect virtually all environments. As per the World Bank data, waste generation levels are approximately 1.3 billion tons per year, and are expected to increase to approximately 2.2 billion tons per year by 2025. Modern lifestyle is responsible for increasing a waste generation; the data represents a significant increase in per capita waste generation rates, from 1.2 to 1.42 kg per person per day in the next fifteen years. Thus, the situation requires urgent plans and strategies for the management of waste and associated complications. Bioremediation is a green approach to reduce the enormous waste and reduce pollutants which harm the environment; therefore, bioremediation is an irreplaceable weapon for vast application in the monarchy of environmental protection.

I. Introduction

Urbanization and excessive extraction of natural sources resulted in large scale pollution and contamination. Deforestation for agricultural land as well as, for industrialization added a harmful impact on the environment. We are converting a green forest into a concrete forest, most of the part of the land we covered with buildings, roads and industries and these are the man-made waste which harming all forms (soil, air, and water) of the environment.

The soil is contaminated by the industrial waste, municipal waste as well as by the chemicals (fertilizers and pesticides) we used in agricultural and a big mountain of household waste shows that how much litter we are producing and what will be the future of the planet. Like soil, water is also contaminated by sewage from domestic households, dumping solid wastes in rivers and other water bodies, for treatment of industrial effluent thousand litter of freshwater is used, oil spills is one of the major source of contamination in marine, groundwater is also contaminated by the agricultural chemicals like fertilizers and chemicals. Forest fires combustion of gasses, traffic, and industrial plants release a huge amount of carbon dioxide and hydrocarbons which depleting the quality of air. Contamination of toxic chemicals in air, water, and soil directly affect the human health. Many diseases like cancer, asthma, and allergies are associated with pollutants. Exposure of pollutants in daily life, cause a harmful and long-lasting effect on human body. As the technology continues to grow, the demand for new products increase automatically, people don’t think twice before changing their old gadgets and other daily life things with a new one just because of new features and technology is used in it. They don’t understand how much waste they are generating day by day by sending their old things to dumps and we think we dump that stuff by subtracting them out of our lives, not from the environment and these stuff not only increase waste but also affecting our health and environment. Electronic devices and other daily life used things have so many toxic compounds which affect human health and the environment if not disposed of properly here we listed some
toxic compounds which are generated by our daily used things and their effect on our body. Some of the toxic compounds with their sources and diseases associated with them are listed below in table 1.

Now the question arises how to get rid of that much big amount of waste and pollutants. Using chemical treatment for industrial waste is not a beneficial strategy. This even adds more toxic chemicals to the environment and causes pollution again, so only treatment which is suitable for reducing the pollution in a greenery approach is bioremediation.

Bioremediation is a remedy in which microorganism and plants remove the contamination by decomposing the pollutants into a harmless natural product such as water (H₂O), carbon dioxide (CO₂) or other non-toxic organic compounds. As resulted bioremediation can be defined as a green technology in which specific microorganism is used to convert hazardous waste into non-hazardous waste or sometimes complete removal of waste from the contaminated site. Bioremediation is defined in many ways however some definitions restrict to the use of microbes only while some definitions defined bioremediation as biological treatment to reduce the toxic waste into non-toxic compounds in which all the biological entities such as plants, microbes and rather the plant-microbe interaction in root zone is included and play a major role in bioremediation.

In this paper, we broadly describe the role of bioremediation and their types as a green technology for removal of waste from the environment. Here we are explaining how the plants and microbes convert the toxic compounds into the non-toxic compounds naturally, which mechanisms they used and how much effective these approaches are to reduce a large amount of waste from the soil, water, and air and what is a current status of bioremediation technology.

### 2. Bioremediation

Nature has its own way to dealing with the contamination and pollution to make itself clean so bioremediation is a natural process in which biological entities is involved, because it is a natural process so it takes a time or we can say that it is a slow process, but our fast development and lifestyle resulted in a high amount of contamination and we want an instant cleanup approach which is not possible with natural process at least. We have to modify those natural processes by providing them favorable condition as well as nutrients, increasing the number of microorganism at the contaminated site or genetically modified those organisms for specific contamination. On the basis of above explanation we can define bioremediation as a technique in which we provide the condition to biological entities to increase their efficiency of degrading hazardous contamination into harmless product or sometimes complete cleanup or Bioremediation uses biological agents, mainly microorganisms i.e. yeast, fungi or bacteria to clean up contaminated soil and water (Strong and Burgess, 2008). Types of bioremediation are shown below in fig.1.

#### 2.1. Types of bioremediation

- **Natural:** Bioremediation has been starting with the starting of contamination, decomposition of dead vegetation and animal into natural products is considered as natural bioremediation.
- **Managed:** In this technique, the remediation process is managed by people to provide essential nutrients to the microbes for increasing the rate of remediation.

<table>
<thead>
<tr>
<th>Toxic compounds</th>
<th>Body parts affected</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadmium</td>
<td>Renal system, respiratory system, cardiovascular system</td>
<td>Batteries, cigarette smoke</td>
</tr>
<tr>
<td>Lead</td>
<td>Immune system, cardiovascular system</td>
<td>Cathode ray tube (CRT) screens, paints, some processed food</td>
</tr>
<tr>
<td>Arsenic</td>
<td>Skin</td>
<td>Water treated wood</td>
</tr>
<tr>
<td>Carbon mono oxide</td>
<td>Nervous system, cardiovascular system</td>
<td>Car exhaust</td>
</tr>
<tr>
<td>Methyl chloride</td>
<td>Hepatic system</td>
<td>Paint removers, auto part cleaners</td>
</tr>
<tr>
<td>Mercury</td>
<td>Skin</td>
<td>Thermostats, thermometers</td>
</tr>
<tr>
<td>Gasoline ,Fuels oils</td>
<td>Skin</td>
<td>Petrol, petrol combustion</td>
</tr>
<tr>
<td>Chlorofluorocarbon (CFC)</td>
<td>Nervous system, skin, Immune system,</td>
<td>Insulation foam, Cooling system,</td>
</tr>
<tr>
<td>Pesticides</td>
<td>Nervous system, reproductive system</td>
<td>Unwashed fruits and vegetables, ground water</td>
</tr>
</tbody>
</table>

### Table 1: Toxic compounds, their sources and effects on human health
Composting: Compost is a mixture of biodegradable waste, like a vegetable, decayed plant waste, and animal dung or sometimes commercial fertilizer. It has a big amount of microorganisms. It has long been used by small farmers and gardeners’ to increase the fertility of soils and yield of crops. Composting is an aerobic decomposition of waste which required carbon dioxide water and nitrogen, now a days it is widely used in the removal of toxic TNT (2, 4, 6 Trinitrotoluene) from the soil.

In Situ: In situ is a Latin word which means ‘in the original place’ it is a technique to treat waste at the contaminated site. There are so many examples of using in situ bioremediation for cleanup of the oil spill e.g. in situ bioremediation was uses for the cleanup of the Exxon Valdez oil spill in Alaska (1989). It spills about 11 to 38 million gallons of crude oil and this is examined to be one of the big. It is considered to be one of the most ruinous human-caused environmental disasters and to get rid of this problem fertilizers and nutrients were used to increase the efficiency of a microorganism to remove the oil from beaches.

Bioventing: Bioventing is the technique of supplying oxygen to the contaminated site. It is mainly used to reduce a petrochemical compound, including gasoline, fuel oil, and bitumen. These are the toxic compounds and together known as total petroleum, hydrocarbons (TPH). Bioventing also reduce a complex of those compounds which is known as BTEX (benzene, toluene, ethylbenzene, and xylenes). These organic solvents are highly toxic and prominent contaminant in nature. A laboratory test comparison between bioventing and other methods, bioventing reducing more toluene and decane and another petroleum hydrocarbon (Malina 1998).

All the bioremediation type mentioned above is the eco-friendly type and no chemical or hazardous method is used to increase the efficiency and growth of microbes so bioremediation is not only safe but also a green technology of reduction of contaminates.

2.2. Special features and limitation of bioremediation

Some special features of bioremediation are as follows: (i) Bioremediation is a natural process so it’s a safe, and time taking eco-friendly approach, (ii) Microbial population is increased in number and degraded the contamination and with reduction of contamination, it decreases simultaneously, (iii) Bioremediation can carry at a contaminated site so no transportation required, (iv) Bioremediation is a cost effective process, it requires less effort and instrumental setup in comparison to other treatment processes, (v) The byproduct of bioremediation is safe; it converts complex toxic compounds into harmless natural organic compounds, (vi) It does not require any harmful chemical catalyst to enhance the rate of degradation we simply used oxygen, water, and other natural nutrients to increase the growth of microorganisms, (vii) Plants and trees eliminate so many toxic compounds by absorbing them from soil and convert them into non-toxic volatile compounds and (viii) Bioremediation is a green technology to reduce the pollutants from air, water, and soil.

Besides several merits, some limitations are also important drawback in the processes of bioremediation. These are as below:

1. It is limited to biodegradable compounds only other compound which is not biodegradable is susceptible to removal.
2. It is a natural process so it takes more time in comparison to other chemical and mechanical process.
3. Proper monitoring of nutrients and other factors like oxygen in case of aerobic bacteria for better results.
4. The biological process is very specific so we have to be specific for the nutrients and other essential factors.
based on the contamination and type of mechanism in which microorganism work.
5. More research is required to develop the genetically modified microorganism and plants to increase the efficiency of degrading the complex toxic compounds which are potentially harmful substances to the environment.
6. There may be susceptibility of more toxic byproducts than the parent compounds.
7. It is difficult to get same results from laboratory scale to field operation.

3. Some toxic pollutants in environment

A huge amount of heavy metals released every day to the environment from human activities, like fossil fuel combustion, mining, use of fertilizer and pesticides, smelting and sludge amendment, add a toxic compound into the environments, which are organic and inorganic in nature. Some of them are extremely harmful to the environment, even in a very low amount for example - Arsenic, mercury, chromium, cyanide, petroleum hydrocarbons, pesticides, endocrine disrupting chemicals, etc., which are explained as below:

**Arsenic** - Arsenic is one of the most hazardous metal found in water and soil, the source from where arsenic is released is smelting of metals, pharmaceutical industry (medicines), pesticide, wood preservation, cattle and sheep dips, feed additives, dye, petroleum, coal, and wood-burning, semiconductor manufacture and waste incineration. The high amount of arsenic in drinking water causes skin manifestation, vascular disease including arteriosclerosis, peripheral vascular disease and ischemic heart disease (ISHD), renal disease, neurological effects, cardiovascular disease, chronic lung disease, cerebrovascular disease, reproductive effects and skin cancer, lungs, liver, kidney, and bladder. Increased exposure of arsenic is also associated with non-insulin dependent diabetes mellitus (Rahman et al. 1998; Wang et al. 2003).

**Mercury** - Source of the high amount of mercury into the environment is coal combustion, iron and steel industry, chloralkali plants, cement industry, waste disposal and brick manufacturing, instruments, clinical thermometers. (Mukherjee et al. 2008) by these sources mercury reached to water and contaminate the water bodies and through water it will affect the fishes and as we know that fish are the main source of food for human, birds and some animals and mercury can seriously damage the health of these species.

**Chromium** - Chromium contamination if mainly found in the tannery effluent. Cr is mainly used by the leather, textile, and steel manufacturing industry; Chromium can affect the air quality through coal manufacturing, which eventually can lead to water or soil contamination. Water contaminated with chromium will not build up in fish when consumed, but will accumulate on the gills, thus, causing negative health effects for aquatic animals; chromium uptake results in increased mortality rates in fish due to contamination. Chromium VI is the most dangerous form of chromium and may cause health problems including: allergic reactions, skin rash, nose irritations and nosebleed, ulcers, weakened immune system, genetic material alteration, kidney and liver damage, and may even go as far as death of the individual (Costa 1997).

**Cyanide** - Hundreds of tons of CN being used in gold mining annually (Ebel et al 2007). It is also used in pesticide and insecticides, and also present in smoke from building fires. Exposures of cyanide cause permanent paralysis, nervous lesions and kidney damage in human.

**Petroleum hydrocarbons** - It has been estimated that annually ~ 6 million tons of petroleum reach the ocean. Petroleum refineries generate a huge amount of waste oily sludge, in terms of tank bottom and effluent treatment plant (ETP) oily sludge, and oil contaminated soil in their daily refining process. The hazardous oily waste is composed of total petroleum hydrocarbons (TPH), water, and sediments (Dibble et al. 1979). Oil contamination has a toxic effect on the environment (Mandal et al. 2007; EPA undated). Crude oil exposure may cause damage to lungs, liver, kidneys, intestines and other internal organs. Polycyclic aromatic hydrocarbons (PAH) may lead to cancer. Inhalation leads to a headache, nausea, dizziness, respiratory irritation, BTEX (Benzene, Toluene, Ethyl benzene & Xylene) cause mutations, cancers, birth defects, nervous disorders, and liver disease, depression, irregular heartbeats etc. (Gomer et al. 1980; Knaffa et al. 2006).

**Pesticides** - Pesticides or xenobiotics widely used in agricultural to inhibit the growth of pest in the crop, pesticides is one of the major source of pollution which harm all the forms of the environment (air, water, and soil). The use of pesticides decreases the general biodiversity in the soil. Pesticides are a threat to wildlife; it also can kill the bees and cause a decline in pollination, thus preventing the fruiting and reproduction in plants.

**Endocrine disrupting chemicals** - Pharmaceuticals and healthcare products that are refractory in function have been detected in drinking water. These include estrogen and anthropogenic endocrine disrupting chemicals (EDC) (Prasad et al. 2010). The investigation proves that veterinary diclofenac is the prime cause for the declined vulture populations. The veterinary diclofenac is in heavy use in the livestock sector (buffalos, cattle, sheep, and goat). In the course of treatment, if the cattle dies, and the vultures scavenge the corpses of cattle. It leads to dehydration, visceral. Pharmaceutical residues are common contaminants of groundwater in many cities gout, and kidney failure in vultures within a few days. There has been increasing concern about the potential adverse effect of endocrine disrupting chemicals (EDC) on environmental health.

4. Application of bioremediation as green technology

Bioremediation is only green technique in which biological entities is successfully used for removal of hazardous compounds from soil, groundwater and air. Many types of
plants with rhizosphere microorganism are highly active in removing or immobilizing the hazardous compounds from soil, groundwater, and air. No chemical treatment no scale-up is required so plantation of that tree or plant is a greener approach to reducing pollutants from soil, water, and air. Construction of green walls or roofs for removal of particulate and gaseous contaminants from the air is a suitable example of reduction of pollutants by green technology. Plantation has been used to cover dust in so many countries, and this technique is called Phyto filtration. A 9m wide green belt may reduce 2 to 3 times of dust fall (Singh and Tripathi 2007). In comparison to all types of treatments like physical, chemical and mechanical including microbial bioremediation phytoremediation technology is one of the best resulted and self-maintaining and green technologies to meet greater public approval. (Doety et al. 2007) Plant-microbe and plant-microbe interaction is removing the pollutant by phytoremediation, bioremediation and rhizoremediation respectively. (Ma et al. 2011, Schroeder and Schwitzguebel 2004) as shown in figure 2.

The major mechanism on which microbes, plant, and plant-microbe interaction used to degrade hazardous compounds into non-hazardous compound are phytovolatilization, phytosequestration, phytodegradation, phytoextraction, rhizodegradation, phytohydraulics. (Dowling and Doty 2009; Ma et al. 2011, Weyens et al. 2009) which is described below:

**Phytoremediation** - Green plants are used for in situ soil phytoremediation (Brooks 1998) which is a green as well as eco-friendly approach. Phytoremediation is defined as use of green and higher plants to clean up soil and water contaminated with inorganics and organics pollutants. Phytoremediation is one of the most advantageous approach for removal of toxic compounds from contaminated soil the cost of phytoremediation is very low, plants can easily monitor and it uses a natural process which is cheap and eco-friendly.

**Phytovolatilization** - Phytovolatilization is the volatilization of toxic compounds from the leaf stomata of plant or from the plant (Anonymous 2009).

**Phytosequestration** - The three mechanisms of phytosequestration that reduce the mobility of the contaminant and prevent migration to soil, water, and air are as follows: Phytochemical complexation in the root zone: Phytochemicals can be exuded into the rhizosphere, leading to the precipitation or immobilization of target contaminants in the root zone. This mechanism of Phytosequestration may reduce the fraction of the contaminant that is bioavailable. Transport protein inhibition on the root membrane: Transport proteins associated with the exterior root membrane can irreversibly bind and stabilize contaminants on the root surfaces, preventing contaminants from entering the plant. Vacuolar storage in the root cells: Transport proteins are also present that facilitate the transfer of contaminants between cells. However, plant cells contain a compartment (the
“vacuole”) that acts, in part, as a storage and waste receptacle for the plant. Contaminants can be sequestered into the vacuoles of root cells, preventing further translocation to the xylem.

**Phytodegradation** - Specifically, phytodegradation, also called “phytotransformation,” refers to the uptake of contaminants with the subsequent breakdown, mineralization, or metabolization by the plant itself through various internal enzymatic reactions and metabolic processes. Depending on factors such as the concentration and composition, plant species, and soil conditions, contaminants may be able to pass through the rhizosphere only partially or negligibly impeded by phytosequstration and/or rhizodegradation. In this case, the contaminant may then be subject to biological processes occurring within the plant itself, assuming it is dissolved in the transpiration stream and can be phytoextracted.

**Phytovolatilization** - Phytovolatilization is the volatilization of contaminants from the plant either from the leaf stomata or from plant stems (Anonymous 2009). Chemical characteristics such as the Henry’s constant, and vapor pressure dictate the ability of organic contaminants to volatilize. In some cases, a breakdown product derived from the rhizodegradation and/or phytodegradation of the parent contaminant along the transpiration pathway may be the phytovolatilized constituent. This effect was studied for the uptake and phytovolatilization of trichloroethene (TCE) or its breakdown products in poplars (Anonymous 2009). Similarly, certain inorganic constituents such as mercury may be volatilized as well. Specifically, Tobacco plants have been modified to be able to take up the highly toxic methyl-mercury, alter the chemical speciation, and phytovolatilize relatively safe levels of the less toxic elemental mercury into the atmosphere (Anonymous 2009). Plants take up water and the contaminants. Some of these contaminants can pass through the plants to the leaves and volatilize into the atmosphere at comparatively low concentrations. Mercury has been shown to move through a plant and into the air in a plant that was genetically altered to allow it to do so. The thought behind this media switching is that elemental Hg in the air poses less risk than other Hg forms in the soil. This method is a specialized form of phytovolatilization that can be used only for those contaminants that are highly volatile. Mercury or selenium, once taken up by the plant roots, can be converted into non-toxic forms and volatilized into the atmosphere from the roots, shoots, or leaves.

For example, Se can be captured by Brassica and other wetland plants, and converted (for example, by methylation to the volatile dimethyl selenium) into nontoxic forms which are volatilized by the plants. Field testing has shown this to be a potentially effective method. A similar mechanism can be exploited for Hg, although there are no naturally occurring plants that can accomplish this. The goal here is to engineer bacterial genes for mercury reduction into plants, and here too laboratory experiments are highly encouraging as mercury breathing out plants is developed in vitro (Heaton et al. 1998).

**Rhizodegradation** - Removal of toxic metals from contaminated soil occurs when inorganic ions are taken up by plant roots and translocated through the stem to aboveground plant parts. Soil microflora of plant roots (rhizosphere zone) is involved in xenobiotic metabolism. The catabolic activity within the rhizosphere has been attributed to both bacteria and fungi whose presence and enzymatic expression are believed to be modulated by organic chemicals released from both living and dead roots. Both the direct and indirect degradation of soil contaminants by plant root physiology and biosynthetic pathways can potentially occur at the lowest depth of root penetration, a special feature of plant remediation. (Rajkumar 2009; Mackova et al. 2006).

**Phytohydraulics** - Phytohydraulics is the ability of vegetation to evapotranspire sources of surface water and groundwater. The vertical migration of water from the surface downward can be limited by the water interception capacity of the aboveground canopy and subsequent evapotranspiration through the root system. If water infiltrating from the surface is able to percolate below the root zone, it can recharge groundwater. However, the rate of recharge depends not only on the rooting depth of the species but on the soil characteristics as well.

### 4.1. In soil remediation

Soil is contaminated by landfill/waste dumps, open burning (rubbers, plastic, coal etc.) incineration, refining or distillation of crude oil, carbon-black production, and use coke production etc., these process contaminated the soil with organic and inorganic pollutants. Contaminated soils and waters are the major environmental forms, which affect the agricultural and human health problems worldwide. Bioremediation is a technology that offers the possibility to reduce the hazardous waste by using natural biological entities. Bioremediation offers a series of process for waste treatment, so it is an important consideration to decide that which approach suited best according to the waste and soil condition?

**Phytoextraction:** is used for the removal of heavy metals pollutants like Cadmium (Cd), Lead (Pb), Arsenic (As), Petroleum hydrocarbons and radionuclides by using the specific plants (Viola baoshanensis, Sedum alfredii, Rumex crispus, Helianthus annus, Alfaifia, poplar, juniper, fescue, Indian mustard, cabbage). (Macek et al. 2000; Zhuang et al. 2007).

**Phytotransformation:** is used for the degradation of organic compounds like xenobiotic substances with the help of Canna (Subramanian et al. 2006).

**Phytostabilization:** is used of plants (Anthyllis vulneraria, Festuca arvenensis, Koeleria vallesiana Armeria arenaria, Lupinus albus Hybrid poplar, grasses) to reduce the bioavailability of pollutants like Cadmium, Chromium, Nickel, and lead. (Vazquez et al. 2006).

**Rhizoremediation:** Microorganism (Chlorella vulgaris Holophaga/ Acidobacterium division and a-proteobacteria, Methylobacterium oryzae, Berknolderia sp.) (Madhaiyan et al. 2007) used for removal of toxic compounds from soil like Pb, Ni, As (Zaidi S et al. 2006).
4.2. In water remediation

Water is essential for life actually pure water; groundwater is one of the biggest sources of drinking water on earth. However, in the past few decades, water is contaminated with petroleum hydrocarbons, pesticides, pollutant released from industrial waste, acidic rain, municipal waste. These organic compounds like benzene, toluene, ethylbenzene, and xylene (BTEX) are ubiquitous pollutants hazardous to human health.

Phytodegradation: Plants (Elodea Canadensis, Pueraria thunbergiana, Duckweed parrotfeather, Hybrid poplar) (Garrison et al. 2000) and associated microorganisms degrade organic pollutants like DDT, Explosives, waste and Nitrates from groundwater. (Newman 2004).

Rhizofiltration: Roots (Brassica juncea, Helianthus annus (Sunflowers)) absorb and adsorb pollutants, mainly metals (Zn, Pb, Cd, As), from water and aqueous waste streams. (Dushenkov 1995; Verma et al. 2006).

Phytovolatilization: Phytovolatilization exploits a plant’s ability to transpire large amount of water from their leaf pores (stomata). Some contaminants like selenium (Se), mercury (Hg) and volatile organic compounds (VOCs), can be released through the leaves into the atmosphere. (Cunningham and Ow 1996). It is also being used for remediation of tritium (H3) contaminated water. Some transgenic plants e.g. Arabidopsis thaliana have been found to convert organic and inorganic mercury salts to the volatile and elemental form. (Watanabe 1997).

Phytostabilization: Phytostabilization refers to the holding of contaminated soils and sediments in place by vegetation, and to immobilizing toxic contaminants in soil and water. •

Phytohydraulics: Plants significantly affect local hydrology. Phytohydraulics is the ability of vegetation to evapotranspire sources of surface water and groundwater. The vertical migration of water from the surface downward can be limited by the water interception capacity of the aboveground canopy and subsequent evapotranspiration through the root system. If water infiltrating from the surface is able to percolate below the root zone, it can recharge groundwater. However, the rate of recharge depends not only on the rooting depth of the species, but on the soil characteristics as well. Trees such as Prosopis and Eucalyptus are typical phreatophytes useful in bioremediation (Anonymous 2009).

4.3. In air remediation

Air is one of the important source of life; breathing fresh clean air is enough to kill your whole day stress-but now a days it’s hard to find a clean fresh breathable air in cities, the air or mixture of polluted gas we are breathing is silently killing us. Millions of people die prematurely because of air pollution worldwide. Air pollution is serious environmental pollution like water and soil pollution. There are so many toxic gases which pollute air, released from burning things, using household and industrial chemicals. Millions of cars on the road per day powered by gasoline and diesel engine that burns petroleum and release energy and huge amount of carbon dioxide. Power plants, industrial plants and factories, forest fires, wood fuel burning, gases using in cooling, ozone hole, global warming, there is so many factors that cause air pollution. There is so many gases which pollute air few of them with their sources are listed below in table 2.

These all are most common pollutant in air but out of which, Suspended Particulates matters (SPM) is 50% of total air pollution. (Fuller 1974).

Phytoremediation of Particulate Matter: The use of vegetation as filtering of dust and particulates from the polluted atmosphere is known as phytofiltration. Plants leaves and bark work as a natural sink for particulates matters as they offer site for gravity or wind-blown settlement of particulates (Romney et al. 1963).

Phytoremediation: Chlorophytum comosum L. (spider plant) is among 120 plant species assayed for phyto remediation of pollutants from indoor air. (Soreanu et al. 2013). It has the ability to remove formaldehyde, nitrogen dioxide, carbon oxide, ozone, benzene, toluene, cigarette smoke and ammonia.

Various trees, plants are having super power of air filtration as compare to others, because of that power trees are termed as ‘cities lungs’. Evergreen trees are the highly effective filter for the air filtration.

Table 2 Pullulated gases and their sources

<table>
<thead>
<tr>
<th>Gases</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfur dioxide</td>
<td>Coal, petroleum, and other fuels. Coal-fired power plants.</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>Gas boiler, stove or fuel burning appliances.</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>Greenhouse gas released by engines and power plants</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td>Vehicle-engine and power-plants, indirect greenhouse gases</td>
</tr>
<tr>
<td>Volatile organic compounds (VOCs)</td>
<td>Paints, waxes, and varnishes</td>
</tr>
<tr>
<td>Suspended Particulates matters (SPM)</td>
<td>Traffic fumes.</td>
</tr>
<tr>
<td>Chlorofluorocarbons (CFCs)</td>
<td>Refrigerators and aerosol cans</td>
</tr>
<tr>
<td>Lead and heavy metal</td>
<td>Exhaust fumes and the fly ash</td>
</tr>
</tbody>
</table>

5. Conclusion

There are so many studies showing the bioremediation as a revolution for environmental issues. Bioremediation is cost effective and eco-friendly approach and integrated toolbox for cleanup of environmental pollution. There is so many evidence which shows, the success of bioremediation as a green technology for the removal of toxic compounds. Many microorganisms can breakdown the metals naturally, but it is not enough solution at a large scale.

Genetic modification is urgently required in microorganisms and plants to increase their efficiency and tolerance so they worked easily in adverse condition. Except few limiting factors, this technology has the ability to rejuvenate the contaminated environments effectively. With the exciting new development in this field and focus on interdisciplinary research and using it on gaining the fundamental knowledge necessary to overcome the obstacles facing current technologies and also with respect to ethical, legal, and social issues involved this technology will go a long way in cleaning the environment in near future.

References


Gomer Charles J, David M, Smith (1980) Acute skin phototoxicity in hairless mice following exposure to crude shale oil or natural petroleum oil, Toxicology 18(1):75–85


Richardson M, Bartha R (1979) Plants that hyperaccumulate heavy metals. CAB International, Wallingford, 8:55–94


Richardson M, Bartha R (1979) Plants that hyperaccumulate heavy metals. CAB International, Wallingford, 8:55–94


Richardson M, Bartha R (1979) Plants that hyperaccumulate heavy metals. CAB International, Wallingford, 8:55–94


