Plant-Pollutant Interaction

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Abstract Plants are the primary reservoirs in food chain. They play a key role in the conversion of energy into food. The life on Earth is impossible without plants. With the increasing advances in different fields, the health of plants is deteriorating drastically. Heavy metals have become an environmental concern because of their adverse and detrimental effects on human life. Apart from that, one of the most important components of global change is increase in atmospheric nitrogen (N), which is threatening both the structure and function of the ecosystem. The N cycle is dominated by anthropogenic activity and the emission and deposition rates

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of N are expected to be doubled by 2050, which will greatly increase the number of regions potentially receiving damaging levels of N inputs. Another harmful air pollutant is the tropospheric ozone (O_3) having negative impact on the growth and development of plants. Current concentration of O_3 is decreasing the productivity of forest and crop yields. Future O_3 concentration will increase if the current emission rate stays persistent. In addition, benzene; a volatile organic compound (VOC), is extracted from industries of petroleum and used widely as an additive or intermediate or solvent in many manufacturing industries. Ambient air pollution problems can be caused by the emission of benzene from many sources, even though several organizations and countries have standard guidelines on benzene use. A number of studies have been carried out to study the effect of petro-coke, cement, coal and dust, fly ash, automobile exhaust and other air-borne particulates on different physiological and morphological parameters in plants.

Keywords Phytoremediation • Chromated copper arsenate • Polyaromatic hydrocarbons • Benzene • Nanoparticles

1 Introduction

The evolution of Earth started nearly 4.5 billion years ago. Since that time, formation of earth has been all about changes in the balance and making life more adaptable. As the humans grew in number, evolution in humans also resulted as an integral element in the delicate balance of nature. The growth of humans increased at the expense of other living things as well as the ecosystem. (Purohit and Ranjan 2007). With development in the industrial sector, the numbers of pollutants affecting plant growth are increasing rapidly. Pollution harms the health or survival of all living organisms i.e. humans, animals and plants. Air is polluted significantly by the release of toxic materials and chemicals from different sources. Windcarries the emissions from the industries to hundreds of miles, where they come down from the sky in the form of acid rain, snow and dust rendering acidity in lakes and making them unsuitable for aquatic animals and plants. The humanrace is faced with the challenge of supporting enormous population growth. Basically, there are two types of pollutants, which are discussed below:

I. **Primary pollutants**
Primary pollutants are those particles or gases, which are pumped into the air to make it polluted. These include gases like carbon monoxide from different automobiles exhausts as well as sulfur dioxide from coal combustion.

II. **Secondary pollutants**
Pollutants have a tendency to mix up in the air and form even more complex compounds. When the primary pollutants mix up in the air in a chemical reaction, they result in the formation of even more dangerous chemical. Photochemical smog is an example of secondary pollutant which is formed in the atmosphere

by the reaction of two primary pollutants. Photochemical smog is the product of chemical reactions driven by sunlight and involving NO_x of urban and industrial origin and volatile organic compounds from either vegetation (*biogenic* hydrocarbons) or human activities (*anthropogenic* hydrocarbons).

Plants are affected by a number of pollutants whether it is soil or environmental pollution. Ozone depletion is one of the most alarming situation and is considered as a major concern of environment on Earth. Apart from that, the burning of hydrocarbons in engines of motor vehicles results in the formation of hazardous gases, which include CO, SO_2 (sulfur dioxide), NO_x (NO [nitrogen monoxide]) and NO_2^-—in varying proportions—and C_2H_4 (ethylene), as well as a variety of other hydrocarbons. Additionally SO_2 also originates from domestic and industrial burning of fossil fuels. Industrial plants, such as chemical works and metal-smelting plants, release SO_2, H_2S, NO_2, and HF (hydrogen fluoride) into the atmosphere. Tall chimney stacks may be used to carry gases and particles to a high altitude and thus avoid local pollution, but the pollutants return to Earth, sometimes hundreds of kilometers away from the original source. Ozone (O_3) and peroxyacetylnitrate (PAN) produced in these complex reactions can become injurious to plants and other life forms, depending on the concentration and duration of exposure. Hydrogen peroxide; another potentially injurious molecule, can form by the reaction between O_3 and naturally released volatiles (terpenes) from forest trees (Ozturk 1989; Zeiger 2006).

The concentration of polluting gases, or their solutions, to which plants are exposed are thus highly variable, depending on location, wind direction, rainfall, and sunlight. In urban areas, concentrations of SO_2 and NO_x in the air are typically 0.02–0.5 mL L^{-1}, the upper value being within the range that is inhibitory to plant growth. Relatively long-term experiments at appropriate concentrations of pollutants are necessary to establish the real impact of air pollution on vegetation. The reaction of plants to high concentration of pollutants in short-term experiments may overwhelm the plant's defense mechanisms (Zeiger 2006).

The responses of plants to polluting gases can also be affected by other ambient conditions, such as light, humidity, temperature, and the supply of water and minerals. Experiments aimed at determining the impact of chronic exposure to low concentrations of gases should allow plants to grow under near-natural conditions. One method is to grow the plants in open-top chambers into which gases are carefully metered, or where plants receiving ambient, polluted air are compared with controls receiving air that has been scrubbed of pollutants.

Unpolluted rain is slightly acidic, with a pH close to 5.6, because the CO_2 dissolved in it produces the weak acid, H_2CO_3. Dissolution of NO_x and SO_2 in water droplets in the atmosphere causes the pH of rain to decrease to 3–4, and in southern California polluted droplets in fog can be as acidic as pH 1.7. Dilute acidic solution can remove mineral nutrients from leaves, depending on the age of the leaf and the integrity of the cuticle and surface waxes. The total annual contributions to the soil of acid from acid rain (*wet deposition*) and from particulate matter falling on the soil plus direct absorption from the atmosphere (*dry deposition*) may reach 1.0–3.0 kg

H^+ per hectare in parts of Europe and the northeastern United States. In soils that lack free calcium carbonate, and therefore are not strongly buffered, such additions of acid can be harmful to plants. Furthermore, the added acid can result in the release of aluminum ions from soil minerals, causing aluminum toxicity. Air pollution is considered to be a major factor in the decline of forests in heavily polluted areas of Europe and North America. There are indications that fast-growing pioneer species are better able to tolerate an acidifying atmosphere than the climax forest trees, possibly because they have a greater potential for assimilation of dissolved NO_x, and more effective acid buffering of the leaf tissue cell sap (Zeiger 2006).

2 Effect of Pollutants on Pollinators

Wild bees play an essential role in pollination in temperate zones and are considered as major pollinators (Kevan 1999). The diversity of wild plants is maintained properly by bees (Ashmann et al. 2004; Aguilar et al. 2006; Brittain et al. 2010) as well as the agricultural productivity (Klein et al. 2007; Gallai et al.2009; Lenda et al. 2010). A large number of plant species that depend on insect pollination for seed and fruit production (Wilkaniec et al. 2004; Morandin and Winston 2005; Velthuis and Van 2006) may experience reduced pollination and production when the pollinator species are scarce (Ashmann et al. 2004). Therefore, the decrease in number of bees in the prominent regions of the globe (Steffan-Dewenter et al. 2005; Brittain et al. 2010; Biesmeijer et al. 2006) is pretty alarming.

A decrease in bee population has detrimental effects on both crops and wildflower pollination. It has been recognized that heavy metals are a problem that are affecting not only the large parts of the European Union but also have detrimental effects on bees. A study was carried out to investigate whether heavy metal pollution is a potential threat to communities of wild bees by carrying out the comparison in (i) number of species, (ii) their diversity and (iii) percentage abundance as well as natural deaths or mortality of the emerging bees along two gradients that are independent of pollution caused by heavy metals. These studies were carried out at Olkusz (OLK), Poland and Avonmouth (AVO), UK. The study was designed to measure the richness in bee species and their abundance. The concentration of heavy metal was also recorded in the pollen that was collected by a specific bee species in order to measure the pollution being caused by heavy metals. The heavy metals found were cadmium, lead and zinc in varying amounts. As a result of this study, it was found out that with an increase in the concentration of heavy metals, there is a decrease in the number, abundance as well as diversity of wild bees. Above all, an inverse trend was observed among wild bees and pollution caused by heavy metals. Applying protection plans to wild pollinating bee communities in heavy metal-contaminated areas will contribute to integrated land rehabilitation to minimize the impact of pollution on the environment. This will aid in not only the betterment of the environment but will also be helpful for plants and their pollination (Moron et al. 2012).

Table 1 Heavy metals affecting the type of pollinator population

S. No.	Pollinators	Heavy metals that effect them	Place reported
1.	Butterfly	Cd, Cu, Fe, Mn and Zn	Finland
2.	Butterfly	Cd, Cu and Zn	Netherlands
3.	Bees	Zn, Cd and Pb	Europe, Poland, UK

There are a number of factors, which decrease the communities of wild bees. One of the major factors includes agricultural intensification (Le Féon et al. 2010; Steffan-Dewenter 2003). Others include use of pesticides (Alston et al. 2007; Brittain et al. 2010), the effect of non-native invasive species (Moron et al. 2009), competition with other populations (Walther-Hellwig et al. 2006; Kenta et al. 2007, spread of pathogens (Colla et al. 2006) and genetic introgression (Kraus et al. 2011). Heavy metals have negative effects not only on one or two species but on all the invertebrate diversity (Syrek et al. 2006; Beyrem et al. 2007; Piola and Johnston 2008) Many studies have figured out the impact of heavy metals on pollinators (Nieminen et al. 2001; Mulder et al. 2005). The following table further explains the type of pollinator and heavy metals affecting its population (Table 1).

3 Soil Pollution

3.1 Chromated Copper Arsenate (CCA)

A large number of heavy metals are reported in air, water, soil and plants in the last few decades. Heavy metals have become an environmental concern because of their adverse and detrimental effects on human life (Yang et al. 2007; Ok et al. 2011a, b). Primary source of toxic metals in environment are anthropogenic systems (Ok et al.2007; Ahmad et al. 2012a, b). Soil is the major sink for inorganic pollutants. Many studies have been conducted to evaluate the extent of heavy metal contamination in soil from anthropogenic sources such as mining and smelting activities, steel and iron manufacturing, incineration of waste, production of cement, phosphate fertilizers and pesticides exhaust from automobiles (Chen et al. 2005; Moon et al. 2011; Ahmad et al. 2012a, b).

A preservative known as Chromated Copper Arsenate (CCA) has been used for the protection of wood products from fungal, bacterial and insect decay (Chirenje et al. 2003; Saxe et al. 2007). CCA treated wood serves as a material for construction of private/public housing, fences, playground equipment, picnic tables, walkways, sound barriers and other outdoors wood products (Kim et al. 2007). In CCA-treated wood, arsenic (As) and copper (Cu) act as an insecticide and a fungicide, respectively, and the chromium (Cr) fixes the As and Cu into the structures of cellulose or hemicellulose, as well as the lignin of the wood (Dawson et al.1991).

There are three forms of CCA; A, B and C which are commercially available. Among them the most popular is type C, which is composed of different constituents; namely CrO_3, CuO and As_2O_5 comprising of 47.5 %, 18.5 % and 35.0 % of C type, respectively (APWA 1991). However, in many countries, usage of woods treated with CCA has been banned. The wood treated with CCA leaches Cr, Cu and As into the surrounding environment, thereby increasing the levels of Cr, Cu and As in the soil thus causing negative effects on the environment and humans (Hingston et al. 2001; Solo-Gabriele et al. 2002; Gezer et al. 2005; Kumpiene et al. 2008). Hence, remediation of CCA contaminated soils is necessary to eliminate risks to human and the environment. Several remediation techniques are being used for soil contaminated with heavy metals (Isoyama and Wada 2007; Ok et al. 2011a). Due to several economic and logistic reasoning as well as possible detrimental effects on the ecological equilibrium and sustainable restoration, they have been restricted (Cao et al. 2002; Fries et al. 2003; Yang et al.2006).

Recently, Phytoremediation; a plant based technique for remediation is found out to be cost effective and an environment friendly method of removing heavy metals from the soil (Hakeem et al. 2015). Phytoremediation can be categorized into two types:

(i) Phytoextraction, which is the removal of heavy metals by aboveground parts of the plant,
(ii) Phytostabilization, which is the reduction of heavy metal mobility and availability around the rhizospheric soil.

Three categories of hyper accumulators, indicators and excluders are made depending upon the ability of plants with medium to absorb, accumulate and tolerate heavy metals (Usman et al. 2012). Specifically, plant species that aid in being hyper accumulators can accumulate extreme levels of heavy metals. Studies show that plant species that are native to a particular area can survive better under the stress of toxic metal relative to invasive plant species (Yoon et al. 2006). In the recent decades, contamination of heavy metals by Cr, Cu and As in soil that is adjacent to CCA treated wood has received great attention. A study was carried out to determine the level of pollution based on the concentration of aforementioned heavy metals to evaluate the remediation capacity of plant species native to that particular area grown in CCA contaminated site (Usman et al. 2012). It was noted that the concentrations of metal decrease as the distance between structure of wood treated with CCA and the point of sampling was increased. The results revealed that *Iris ensata* is a hyper accumulator with the highest Cr accumulation (Usman et al. 2012).

3.2 Nitrogen; Its Role Towards Plant Growth

One of the most important components of global change is increase in atmospheric nitrogen (N). This increase is threatening both the structure as well as the functioning of the ecosystem. The global N cycle is dominated by anthropogenic activity (Galloway et al. 2004) and it has been predicted that the emission and deposition rates of N will be doubled by 2050, greatly increasing the number of regions that are potentially receiving damaging levels of N inputs (Bobbink et al. 2010; Galloway et al. 2004). By understanding the responses of ecosystems and the mechanisms by which these mechanisms are driven, these responses continue to be of major importance for the conservation of ecosystems; both natural and semi-natural types, biodiversity preservation and ecosystem services sustainability. Over the least two decades, a number of studies are carried out to understand the N deposition through application of N to experimental plots. Along with these studies, certain survey studies evaluated the patterns of ecosystem response along gradients of N deposition in space and time (Dupre et al. 2010; Maskell et al. 2010) to reveal the diverse impacts on ecosystem structure and function. The major impacts are:

(i) Accumulation of nitrogen causing biodiversity declines through/by the expansion of nitrophilous species and competitive exclusion of others;
(ii) Accumulation of NH_4^+ ions that lead to toxic effects on sensitive species in ecosystems where NO_3 is usually the dominant N form (Stevens et al. 2011);
(iii) Acidification of soil, cation depletion of the base and enhanced toxic metals availability (e.g. Al_3^+, Fe_3^+) which can result in the reduction of health of plants and productivity, alteration in community composition, and cause declines in richness of; and
(iv) Increase in the susceptibility of plants to secondary stresses including increased herbivory, reduced resistance to attack by pathogen or increase in susceptibility to drought or freezing damage (Phoenix et al. 2012).

The role of deposition of N as of driver of biodiversity loss has recently been reviewed (Bobbink et al. 2010; Dise et al. 2011). However, there are certain limitations to these studies as well. Hence, the assessment of deposition of N threat can also be facilitated by the analysis of long-term experiments, across multiple numbers of ecosystems, application of techniques that adequately stimulate deposition of N and also employing realistic doses of N. Deposition of atmospheric nitrogen (N) is becoming global threat to biodiversity and ecosystem function. Much of the current understanding of deposition of N impact comes from manipulation of field studies, although interpretation may require caution where simulations of N deposition (in terms of dose, application rate and N form) have limited realism (Phoenix et al. 2012).

3.3 Stone Crushing

The stone crushing units and the traffic associated with it generates a large number of air pollutants. These pollutants degrade the quality of air in the specific area. The two main operations include:

- Mining or quarrying operations
- Crushing operations

These two operations are responsible for high load that causes pollution. But a lack in the environmental governance in both of the above-mentioned operations has resulted in degradation of environment to a considerable amount around the locations where the stone crushing industry is set up (ES 1998).

The particulates resealed by the above mentioned activities vary a lot in their sizes and weights. They remain as a part of air for varying time length and affect plants and human beings differently (Mishra 2013). Stone dust acts as ‘primary aerosol’ imparting a detrimental effect not only on the environment but also on people and other flora and fauna. The examples include change in the productivity and pH of soil, haze formation leading to reduced visibility in the surrounding areas, habitat destruction, damage to natural resources like important and valuable vegetation and wild lives and at last but not the least, promotion of spreading of many diseases (Semban and Chandrasekhar 2000; Das and Nandi 2002; Mishra 2004).

A number of studies have been carried out to study the effect of petro-coke, cement, coal and dust, fly ash, automobile exhaust and other air-borne particulates on many parameters that include physiological and morphological status in different plants (Singh and Rao 1980; Prasad and Rao 1981; Naidoo and Chirkoot 2004; Prajapati and Tripathi 2008).

3.4 Phthalic Acid Esters (PAEs)

Phthalic Acid Esters (PAEs) accumulation in the plants and soil in agricultural land near a recycling site of electronic waste in east China has become an increasingly evident threat to the quality of neighboring environment and human health. Collection of soil and plant samples from the land under different utilizations including fallow plots, plots for vegetable, alfalfa plots for green manure, fallow plot under long term flooding as well as under alternating dry and wet periods, along with the samples of plants for relative plots was done. Assessment for health risks was conducted on target PAEs, which are known as analogs of typical environmental estrogens based on their accumulation in edible vegetable parts. The potential damage that the target compounds of PAE may pose to human health should be taken into account in further comprehensive risk assessments of recycling sites areas of electronic waste. Moreover, alfalfa removed substantial amounts of PAEs from the soil, and its use can be considered a good strategy for *in situ* remediation of PAEs. Recycling of electronic wastes and dismantling has become an important activity of industrial sector to the local economy in many areas. However, improper and arbitrary methods of recycling have resulted in multiple contamination of environment proceeded by heavy metals, polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins/dibenzo-furans (PCDD/Fs), polycyclic aromatic hydrocarbons (PAHs), and polybrominateddiphenyl ethers (PBDEs). DnBP, DEHP and DnOP are supposed to be the three most frequently detected phthalic acid ester (PAE) compounds in most of the electrical wastes, which explains the discovery of elevated PAE compounds in agricultural soils in recent years (Ma et al. 2013).

3.5 Heavy Metals

Soil pollution with heavy metals is a worldwide environmental problem. Phytoremediation through phytoextraction and phtyostabilization appears to be promising technology for the remediation of polluted soil. It is important to emphasize strongly that the ultimate goal of remediation of heavy metals from the soil is to reduce their mobility and bioavailability. Quality of soil is defined as the capacity of a given soil to perform its ecological functions. Microbial properties of soil are increasingly being used as biological indicator of soil quality due to their quick response, increased sensitivity and capacity to provide information that integrates many factors of environment. Indeed, properties of microbes are among ecologically most relevant indicators of soil quality. Consequently, monitoring of microbial activity is often carried out during phytoremediation of heavy metal processes. However, microbial properties of soil are highly dependent on the context and difficult to interpret. For better interpretation of properties of microbial activity of soil, they may be grouped within categories of higher relevance of ecology such as functions of soil, health attributes of ecosystem and its services (Maria et al. 2012).

Pollution of soil by heavy metals is a worldwide important environmental problem. Anthropogenic activities result in pollution of soil with toxicity of heavy metals. Metallurgy, mining, agriculture, tanning, disposal of waste, fossil fuel combustion and other human activities are responsible for the enormous heavy metals amount and metalloids presently found in our soils. Among these, the most frequent heavy metals found in polluted soil are lead (Pb), cadmium (Cd), cobalt (Co), mercury (Hg), copper (Cu), selenium (Se), zinc (Zn) and nickel (Ni) (Kavamura and Esposito 2010; Hakeem et al. 2015).

The functionality of soil ecosystem is interfered by both inorganic and organic pollutants but special concern is the concentration of heavy metal due to their immutable nature i.e. they do not undergo any biologically or chemically induced degradation. They are highly persistent in the soil. Moreover, heavy metals are potentially harmful to all biota and tend to accumulate in the food chain (Maria et al. 2012).

Unfortunately, traditional way of management of polluted soil with heavy metals using a variety of physicochemical remediation methods (approaches to conventional remedial often involve excavation and washing, landfilling, replacement of soil with clean material, or capping the soil with an impermeable layer to reduce exposure to pollutants) has proven to be economically unattractive, particularly for sites that are largely polluted. Most importantly, some of the technologies that include physiochemical engineering result in deterioration to considerable level of the soil ecosystem. At times, they cause even more damage to soil ecosystem than the pollutants themselves and do not allow reshaping of soil ecosystem naturally. It has been noted that one of our most important resources is soil with a value of estimated $20 trillion (Maria et al. 2012).

Currently, development sectors are focusing on the environment friendly and cost effective methods for the remediation of soil that is polluted with heavy metals. The use of microorganisms for the detoxification or removal of pollutants, also known as, bioremediation is a well-known low-cost option for *in-situ* remediation of polluted soils (Maria et al. 2012).

Nonetheless, pertaining to the remediation of soils polluted with heavy metals, microorganisms have some important limitations:

- They have the ability of heavy metal toxification by valence transformation, precipitation of extracellular material or volatilization, but they cannot remove metals from sites that is polluted. Therefore, it is not a long term, large-scale solution to the highlighting problem of heavy metal pollution in the soil. On the contrary, plants have the ability to extract heavy metals from the soil theoretically rendering them clean (Maria et al. 2012).
- Furthermore, during remediation processes based on plants, plants have the ability to improve the chemical, physical and biological properties of the polluted soil by increasing the porosity, prevention of erosion, addition of nutrients and promising growth of microbes.

3.6 Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) are pollutants of ubiquitous nature with known carcinogenic and mutagenic effects. Several studies showed that PAHs are taken up by plants grown in contaminated soils. Many factors, like the initial concentration of soil PAH, soil physical and chemical properties, the microbial population, and physiological characteristics affect the contaminants uptake. In plants, it is generally agreed upon that sorption controls uptake of chemicals. Carbonaceous materials like unburnt coal, black carbon (soot and charcoal), and kerogen have a great capacity to adsorb hydrophobic pollutants like PAHs. Hence they can control the bioavailability of PAHs (Jakob et al. 2012).

Since a large amount of money is required in order to carry out the excavation of contaminated soil, the *in-situ* stabilization of organic pollutants in soils and sediments has attracted increasing attention in the recent years. The addition of small amount of AC (activated carbon) has been revealed to decrease the bioavailable concentrations of organic pollutants. AC is a processed form of charcoal with a high sorption capacity, likely because of its chemical structure, large surface area and high porosity. Strong sorption of pollutants to AC has been shown to decrease the accessibility of pollutants to microorganisms. In order to check the bioavailability of organic components for soil fauna, earthworms are often used. It is suggested that AC reduces the biota to sediment or soil accumulation factor (BSAF). Little attention has been directed towards the possible toxic effects of AC on sediment or soil dwelling organisms. In a study, Jonker et al. (2009)found ecological toxicity affects of AC in AC-water and AC-enriched sediment systems. However, in two other studies, changes were observed in the lipid concentration in different plants affected with AC.

In addition to that, two other studies revealed the possibility that AC results in the reduction of the bioavailable concentration of essential substances leading to the nutrient deficiency for soil and sediment organisms as well as for plants. The physical, microbial and chemical characteristics of the soil may also be affected by AC. Additionally, this may also have harmful or adverse effects on plant and soil organisms. A study was carried out which involved the investigation of AC performance (powder and granular) amendments as an *in-situ* technique for stabilization of soil that is contaminated. The study involved the elucidation of AC impact on the uptake of PAH by earthworms and plants in an urban soil contaminated with PAH. It was also noticed whether the addition of AC had toxic effects on plants and earthworms and whether or not the different kinds of AC affected the chemical and physical parameters of soil. This is, till now, the first field study for the investigation of *in-situ* sequestration capacity of AC in a soil contaminated with PAH as well as the effects of different AC amendments on plants and earthworms (Jakob et al. 2012).

3.7 Zinc; Afront Line Pollutant

Zinc (Zn) pollution is very prominent and plays an important role in plant growth. A study was conducted on the interaction between Zn pollution and rhizosphere microorganisms as well as plants. The influence of two strains of bacteria isolated from a Zn polluted soil was tested. Zn polluted soil affected the growth of plant and the efficiency of symbiotic native ArbuscularMycorrhizal Fungi (AMF). Zn tolerance was exhibited by two strains of bacteria cultivated under increasing levels of Zn in the medium. However, strain B-I showed higher Zn tolerance than strain B-II at the two highest levels of Zn in the medium. Results revealed that strain B-I consistently enhanced growth of plant, phosphorus and nitrogen accumulation and number of nodules and infection of mycorrhiza, which demonstrated activity of its plant growth promoting (PGP). It was recorded that the strain B-I produces IAA and accumulate 5.6 % of Zn from the growing medium. The increased nutrition and growth of plants dually inoculated with the AMF and B-I bacterium was observed at three levels of Zn. This effect can also be related to the stimulation of symbiotic structures and decreased concentration of Zn in tissues of plants. The amount of Zn acquired per unit weight of root was reduced by each of these strains of bacteria or AMF and particularly by the mixed AMF-bacterium inocula. This clearly explains the alleviation of toxicity of Zn by selected microorganisms and indicates that metal-adapted bacteria and AMF play a key role in enhancing growth of plant in soil contaminated with Zn (Vivas et al. 2006).

Zn is an essential metal for normal growth of plant and its development since it is a constituent of many enzymes as well as proteins. However, increased concentrations of this metalis toxic to many living organisms. Elevated Zn concentrations exist in many agricultural soils due to management practices that include sludge sewage application or usage of manure of animal and from activities that involve mining. Many evidences suggest that microorganisms are far more sensitive to stress caused by heavy metals than plants or animals (Vivas et al.2006).

In recent years, several studies have revealed the harmful effects caused by metals in increased concentrations on diversity of microbes and activities carried out by them in the soil. Zinc occurs only as the divalent cation Zn^{+2}, which does not undergo the redox changes under the biological conditions. It is a component in many enzymes and proteins that involve DNA-binding e.g. zinc-finger proteins, which exist in bacteria. As far as humans are concerned, toxicity of zinc may be based on zinc-induced deficiency of copper. However, the toxicity of zinc is much less as compared to copper. In *E.coli*, zinc toxicity is similar to that of nickel, cobalt and copper. It is observed that AMF are microorganisms of soil that establish mutual symbiotic relation with majority of the roots of higher plants, providing a direct physical link between plant and soil roots. They are found in usually all habitats and all climates. Thus, changes in population of AMF diversity produced by the presence of increased amounts of metals are expected to interfere with the possible beneficial effects of this association (Vivas et al. 2006).

The mycorrhizal symbiosis generally occurs in the presence of many microorganisms and this hypothesis is supported by abundant amount of literature. The literature further reveals that interaction of some of the microbes is specific and there are certain ways of influencing the mycorrhizal relationship and its effects on growth of plants. Thus, the microorganisms are associated with complement activity of mycorrhizae. One of these groups of bacteria, the so-called rhizobacteria which enhances the growth of plants known as plant-growth-promoting rhizobacteria (PGPR) has been reported by a number of others to have interacted with AMF. The final effect of microorganisms of soil that includes AMF, on the development of plants is the result of interactions among different microbial components that are involved. In contrast to that, only a few studies focus on the interactions between PGPR and AMF along with heavy metals as source of disturbance of soil. A significant increase in the growth of plant has been observed in the presence of heavy metals that include lead, zinc and nickel. However, the manipulation of combination of beneficial microorganisms is dependent upon the proper understanding of ecosystem in order to apply a suitable selection of microbes. In a study, the inoculation effect with two indigenous isolates of bacteria on a plantwas observed. Along with that, Zn tolerance on AMF was studied in terms of growth of plants, uptake of nutrients, acquisition of zinc and development of symbiosis. The strains of microbes used were isolated from areas contaminated with Zn for a long term. Microorganisms were assayed in single or dual coinoculation artificially in the soil contaminated with a range of Zn levels. Production of bacterial Indole Acetic Acid (IAA), ability of zinc biosorption and the number of viable bacterial cells at increasing levels of Zn were also determined (Vivas et al. 2006).

4 Air Pollution

4.1 Benzene

Benzene; a volatile organic compound (VOC), is extracted from industries of petroleum and used widely as an additive or intermediate or as a solvent in many manufacturing industries. Ambient air pollution problems can be caused by the emission of benzene from many sources, even though several organizations and countries have standard guidelines on benzene concentrations (PCD 2007). It is found that concentration of benzene in the atmosphere is higher than the local standard. In addition to this, 9 cohort and 13 case control studies confirmed that benzene can clearly induce many types of cancers including acute myelogenous leukemia. Many researchers have classified benzene in IA group, which is composed of carcinogens having high potential in human body by IARC. Other diseases that are likely to be caused by benzene include allergies, asthma, dizziness, tremors, eye irritation, restlessness and disorders of nervous system. Environment also has a tendency to accumulate and store benzene. Studies revealed that some plant species have the ability to take up gaseous benzene through the automata and wax on leaf surface (Treesubsuntorn et al. 2013).

A recent study showed that even when plants are grown under dark conditions, the plant could still take benzene up via cuticular wax because at night the stomata are closed. Many scientists found benzene accumulation in the cuticular wall. These days, for the treatment of benzene, activated carbon is widely used. However, there is a problem in the secondary waste disposal as well as high control cost. Use of plant leaf material for adsorption of benzene is beneficial in a way of a low cost adsorbent (Treesubsuntorn et al. 2013).

4.2 Ozone

Another harmful air pollutant is the tropospheric ozone (O_3) that has negative impact on the growth and development of plants. Current concentration of O_3 is decreasing the productivity of forest and crop yields. Future O_3 will increase if the current emission rate continues. When data from different studies were compared, it was noted that ambient O_3 decreases the seed number by nearly 16 % as well as fruit number and fruit weight by 9 % and 22 % respectively as compared to charcoal filtered air. Additionally, germination of pollen and tube growth were also decreased by elevated concentration of O_3 compared to charcoal filtered air. Relative to ambient air, fumigation with O_3 between 70 and 100 ppb decreased fruit yield by 27 % and individual seed weight by 18 %. Reproductive development of both C_3 and C_4 plants was found to be sensitive to elevated O_3 and lifecycle, flowering class and reproductive growth habit did not significantly affect a plant's response to elevated O_3 for many components of reproductive development. However, elevated O_3

decreased weight of fruit and its number significantly in indeterminate plants, and had no effect on these parameters in determinate plants. While gaps in knowledge remain about the effects of O_3 on plants with different growth habits, reproductive strategies and photosynthetic types, the evidence strongly suggests that detrimental effects of O_3 on reproductive growth and development are compromising current crop yields and the fitness of native plant species (Ainsworth and Leisner 2012).

Studies reveal that development of sexual reproduction is a critical stage in the plant's life cycle and many other stages of reproductive development are sensitive to this ozone. Ozone is basically a secondary pollutant that is formed by the oxidation via photochemical pathway of methane, carbon monoxide and other volatile compounds that are organic in nature (VOCs) in the presence of oxides of nitrogen (NOx). During warm and sunny weather, the formation of O_3 is the greatest, which coincides with times of maximum plant growth and reproductive development. Therefore it is considered as one of the most damaging tropospheric air pollutants. A considerable increase in the concentration of O_3 is observed since the industrial revolution in past 60 years. It is likely that the concentration will further increase by 10–30 parts per billion (ppb) by 2100 if the practices in Northern hemisphere are not put to an end (Ainsworth and Leisner 2012).

This increase is substantial considering the current tropospheric concentration less than 40 ppb in most parts of the world. These concentrations are believed to increase and exceed the international environmental criteria for protection of crop as well as natural vegetation and human health. Ozone enters the plants through their stomata, which is also the site of carbon dioxide (CO_2) uptake. Once taken up by the plant, O_3 rapidly reacts to form other reactive oxygen species (ROS), including hydrogen peroxide, singlet oxygen and hydroxyl radicals. Increased levels of ROS can lead to programmed cell death. ROS influx can also change the redox potential, levels of hormone and peroxidation of lipids in the apoplastic and intercellular spaces within plant cells. Reduction in photosynthesis and conductance by stomata in leaves are reduced by chronic exposure to O_3 that leads to reduced production in biomass and reproductive crop output. However, it still remains unclear that what proportion of decrease in the reproductive output is caused by direct damage to reproductive processes such as initiation of flower, development of ovary and pollen and abortion of seed as opposed to damage to the vegetation that subsequently reduces availability of assimilate to reproductive development. Ozone can have a direct effect on the reproductive structures of plant i.e., stylar and stigmatal surfaces, anthers, pollens, floral sites, seeds as well as fruits. The entry of O_3 via apoplastic space gives rise to the production of ROS, which eventually causes changes in surfaces of stigma and membranes of cells. The ability of pollen to germinate stigmatal surface is also affected by ROS. Moreover, a change is mediated by ROS in the cellular redox environment that can potentially lead to changes in the growth of pollen tubes, which is critical for embryo fertilization. Ozone (O_3) affects all the reproductive growth and development of plants. Nearly a decade ago, effect of O_3 on reproductive development of plant was reviewed, but recent quantitative assessments have focused on the influence of O_3 on growth and development of vegetative parts of plants or yield of crop. The complex nature of O_3 affects the vegetative and reproductive structures, a range of compensatory mechanisms available to plants with different habits of reproductive growth, the dependence of development stage of plants on sensitivity level and the consequences of environmental stresses, in addition, make it difficult to generalize O_3 effects on reproductive development (Black et al. 2010). Still, understanding O_3 effects on the reproductive development has significant ecological and agronomic consequences that include securing food resources for the future and ensuring the fecundity and composition of species of native flora. For this verification, meta-analysis was used to test the following:

1. Moderate increase in O_3 is enough to cause decrease in reproductive growth parameters in plants with increasing O_3 resulting in more severe effects on reproductive growth
2. Plants exposed to increased levels of O_3 with additional abiotic stresses will not experience a larger decrease in growth of reproductive parts and output when compared to plants that are exposed to elevated O_3 alone
3. Less sensitivity will be shown by C4 plants towards O_3 due to lower conductance in stomata and O_3 uptake
4. At last, determinate plants with decreased flexibility in flowering will have a limited compensatory response for loss of reproductive sites, rendering them more sensitive to increased O_3 concentration than indeterminate plants (Ainsworth and Leisner 2012).

4.2.1 Tropospheric Ozone; Deeper Roots

Tropospheric ozone is currently considered to be the most important air pollutant affecting vegetation and a further increase in background ozone concentration over the coming century throughout the northern hemisphere has been predicted as a result of large increases in emissions of precursor molecules from transport and industry. Summer mean ozone concentrations across Europe are expected to reach 40–60 ppb by 2030 and some models predict that annual mean ozone concentrations could exceed 75 ppb over much of the northern hemisphere by 2100. Several studies have shown that responses of plants are better related to accumulate stomatal fluxes of ozone than to the external ozone concentration, and the flux method is being used by the Convention on Long-range Transboundary Air Pollution (LRTAP Convention) to assess the risk of ozone damage to vegetation across Europe. Ozone flux models currently takes into account the effect of climatic conditions such as temperature, vapor pressure deficit (VPD) and photosynthetically active radiation (PAR), soil moisture content, and plant growth stage on stomatal opening, and thus are well suited to modeling ozone effects in a changing climate. Changes in precipitation patterns are likely to occur in the next few decades, and although there are predictions of increased humidity in some areas, it is likely that there will be reduced soil moisture across much of Europe. Predictions of future ozone impacts therefore need to take into account the modifying effects of prolonged ozone exposure on plant responses to soil moisture (Hayes et al. 2012).

A generalized flux model has been described by Emberson et al. (2000), which is a multiplicative model based on a Jarvis approach using temperature, VPD, PAR, phenology, ozone and soil moisture as model inputs. However, few studies have included consideration of soil moisture when measuring ozone effects even though soil moisture is a component of the stomatal flux model. In most cases, calculations of stomatal flux have been performed for experiments involving well-watered (WW) plants where restriction of stomatal conductance due to reduced soil moisture was not thought to occur. Until recently, it has been assumed that reduced soil moisture is associated with stomatal closure, leading to reduced ozone uptake, providing some protection to plants from the negative effects of ozone exposure. Such an effect was commonly reported in earlier studies for some species using relatively high ozone treatments, for example in wheat (*Triticum aestivum*; 80 ppb), tomato (*Lycopersicon esculentum*; 68 ppb) and common ash (*Fraxinus excelsior*; 150 ppb). Although the assumption that reduced soil moisture protects plants from ozone exposure is largely accepted, there are a growing number of reports where the reduction in stomatal conductance due to drought has not been as large as expected, particularly in the presence of ozone, and to date these effects have been largely overlooked. For example, in the field, with 8-h mean ozone concentrations of 51 ppb, ozone-induced visible injury in black cherry (*Prunus serotina*) was greater at drier sites than at wetter sites, with higher stomatal conductance measured in the drier than the wetter sites for both black cherry and white ash. Although no mechanism was presented, the authors hypothesized that either the trees had acclimatized to the drier conditions or that water availability was not low enough to induce stomatal closure. In a different study, severe drought stress protected birch (*Betula pendula*) from ozone injury as predicted, but under less severe drought-stress enhanced ozone damage was observed compared to that of WW plants using ozone concentrations 1.89 ambient. Again, the authors suggested no mechanism to explain this effect. The ability of drought to protect natural vegetation plants from ozone injury using ozone concentrations of up to ca. 200 ppb was found to be species-specific in a study by Bungener et al. (1998). While some species showed reduced ozone-induced injury symptoms due to drought-induced stomatal closure (e.g. white clover; *Trifolium repens*), for other species there was either no stomatal closure or an increase in stomatal opening in the presence of drought (e.g. false oat grass; *Arrhenaterum elatius*).

Some recent studies have shown that interactions between soil moisture and ozone can occur which could explain some of these published anomalies. For example, a decreased ability of stomata to close in response to drought in the presence of increasing ozone exposure has been demonstrated for ca. Ten grassland species including *Leontodon hispidus* and *Dactylis glomerata* and the widespread grasses *Anthoxanthu modoratum*, *Lolium perenne* and *Phleum pratense*. This has been attributed to a reduced responsiveness of stomata following elevated ozone exposure, and in particular an ozone-induced decrease in sensitivity to abscisic acid, which is produced in roots as a response to drought and transported to shoots in the xylem, where it induces stomatal closure via a network of chemical messengers.

The increasingly large number of ‘anomalies’ where drought-induced stomatal closure and protection from ozone-induced injuries does not happen suggests that this effect may possibly be fairly widespread among vegetation.

5 Nanoparticles; a New Threat

Among all the factors that influence the quality of soil, biological indicators are reported to be critically important because organisms of soil influence directly the processes in soil ecosystem, especially the decomposition of organic matter of the soil and nutrient cycling. Hence, any factor that affects the biomass of soil microbes, their activity and populations would necessarily affect the quality of soil and its sustainability. At present, an increasing number of engineered nanoparticles (ENPs), that are employed for environmental and industrial applications or are formed as by-products of activities by humans, are finding their way into soils. The antimicrobial activity of these ENPs has been studied extensively with human pathogenic bacteria. Similarly, studies also exist on the effect of ENPs on beneficial microbes *in vitro* under controlled conditions. But very little information is available on how these ENPs affect microbial communities in soil under field conditions. According to some of the published data, among ENPs, the fullerenes and their derivatives are less toxic whereas metal oxide ENPs and small sized metals pose detrimental effect to the microbial communities in the soil. However, under field conditions, organic matter of the soil and its related components, like fulvic and humic acids, could possibly negate the toxic effects of these ENPs through a number of mechanisms. Also, the resilience as well as resistance of microbial communities of soil to such perturbations cannot be discounted (Dinesh et al. 2012).

The quality of soil is usually defined as the capacity of a soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitat. Among the factors that influence quality of soil, biological indicators are reported as critically most important because soil organisms have a direct influence on the ecosystem of soil processes, especially in soil decomposition of the organic matter and the nutrient cycling. Therefore, the protection of microbial biomass of the soil and its diversity is among the major challenges for use of sustainable resource. It is because the increased levels of microbial diversity and biomass means greater turnover in the nutrients and disease soil suppressiveness. The opposite is true for a sick soil with low nutrient and reserves of carbon and greater levels of contaminants that is caused by the presence of chemicals of xenobiotic source or other alteration in the environment of soil. As far as the xenobiotics are concerned, there are staggering number of new nanoparticles being engineered for application in the industrial and environmental sector or are formed as a by-product of human activity which are already finding their way into the soils. While the concentrations of most of the ENPs in the environments still remain unknown, exposure modeling suggests that the soil could act out as a major ENPs sink that is released into the environment.

5.1 Engineered Nanoparticles and Their Toxicity to Microorganisms

Engineered nanoparticles are artificially manufactured particles that are engineered by man because of their specific properties in the field of nanotechnology in terms of properties, size, behavior etc. The question to the answer that why ENPs built material have different electrical, optical, magnetic, mechanical and chemical properties from their bulk counterparts are that in this range of size, quantum effects start to reveal their predominate nature and there is an increased surface-area-to-volume ratio (sa/vol).

The sa/vol of most materials increases gradually as their particles become smaller in size, which results in the increased adsorption of the surrounding atoms and bring about the changes in their behavior and properties, subsequently. Once these particles are small enough, they work under the principles of quantum laws of mechanics. Suddenly, the particles that have been reduced to nano-scale display extremely different properties compared to what they exhibit on macro-scale. This enables unique applications e.g. opaque substances become transparent (copper), the materials that are stable becomes combustible (aluminum), materials that are inert start acting as catalysts (platinum), insulators act as conductors (silicon), some turn to liquids when kept at room temperatures (gold) (Hristozov and Malsch 2009).

ENPs can also be made up of single elements like carbon (C) or silver (Ag) or elements/molecules mixture. ENPs are often classified on the basis of their chemical composition, supplemented with size or morphological characteristics. Many ENPs are described viz. oxides (TiO_2, CuO, FeO_2, ZnO, Al_2O_3, CeO_2, SiO_2), Fullerenes (grouping of Buckminister fullerenes, carbon nano tubes (CNTs), nanocones etc.), ENPs metals (elemental Ag, Au, Fe etc.) and complex compounds like Co-Zn-Fe oxide and quantum dots are often coated with a polymer e.g. cadmium-selenide (CdSe) and polymers of organic compounds (dendrimers, polystyrene etc.). The increasing entry of the ENPs will lead to their accumulation in soil inevitably, which raise concerns about their potential adverse effects on the microbial activity of soil and its diversity. At present very little is known about the effect of these ENPs on the microbial community of the soil. They may have an impact on the microorganisms of soil via the following:

1. a direct effect (toxicity)
2. changes in the bioavailability of nutrients or toxins
3. indirect affects resulting from their interaction with natural compounds of organic nature
4. interaction with toxic organic compounds, which would alleviate or amplify their toxicity (Simonet and Valcarcel 2009).

Mechanisms of toxicity have not yet been completely elucidated for most ENPs. The possible mechanisms include protein oxidation, genotoxicity, energy transduction interruption, formation of reactive oxygen species (ROS) and the release of constituents that are toxic in nature. However, close contact is necessary for disruption of membrane to occur and it is likely that NPs cross into the cytoplasm although accumulation within the cytoplasm, probably after the disruption of membrane is often observed. It was also noted that the antibacterial activity possessed by NPs might involve ROS production as well as NPs accumulation in the cytoplasm or on the outer membranes. Structural changes may also be caused by ENPs on the microbial surface of cells that may eventually lead to cell death. It is, therefore, apparent that ENPs stimulate the production of ROS in organisms and cause damage in possibly every cell component (Bhatt and Tripathi 2011).

6 Role of Forests

European forests are facing significant changes in climate, which, in interaction with changes in the quality of air may affect significantly the productivity of forest, stand composition and sequestration of carbon in both soil and vegetation. Gaps in the identified knowledge and research needs include:

(i) Interactions between changes in quality of air (concentrations of trace gases), climate and other site factors in response to ecosystem of forest.
(ii) Significance of biotic processes in response to system
(iii) Up scaling and understanding diagnostic and mechanistic tools
(iv) Need for empirical research and unifying modeling for synthesis.

The forest ecosystems are crucial ecologically which cover 30 % of the land area of earth. Globally it has been recorded that forests store more than 805 of all the terrestrial carbon (C) aboveground and more than 70 % of all-organic soil carbon. Overall, currently global C sinks are considered to be forests whereas croplands are the sources because of more frequent disturbance in soil associated with practices involving agriculture. By the changes in photosynthesis, soil respiration and respiration, it will be determined whether forests will remain carbon sinks, affecting the net ecosystem of carbon flux. Such processes are strongly affected by the changes in:

(a) Quality of air comprising of deposition of nitrogen (N), atmospheric carbon dioxide (CO_2) concentration, ozone (O_3) exposure and fine particulates/aerosols
(b) Warming of climate with effects on water availability
(c) Soil acidity and availability of non-N nutrients (De Vries and Posch 2010)

These drivers affect sequestration of carbon in both above as well as below ground biomass in the forest ecosystem. Insights into the multi-factorial, influences on quality of air and changes in the climate, is crucial to provide a robust evidence base to policy makers. Such influences arise from the resources of fossil energy combustion and changes in land-use (i.e. clear cutting of forest and its burning), altogether releasing CO_2, oxides of nitrogen (NOx) and other climate related trace gases. Emissions from forests add to those from intense practices of agriculture, specifically ammonia (NH_3) and methane (CH_4) from livestock (Matyssek et al. 2012).

Additionally, natural emissions of organic compounds, which are volatile in nature (VOCs) from vegetation, increase the mixture of reactants in the atmosphere. With the accumulation of trace gases, there might be an increase in their reactivity, if there is an enhancement in the isolation as an effect of warming atmosphere. Under increased irradiance, some of the reactants become precursors to the formation of secondary pollutants such as O_3. With its concentration well above the levels of pre-industrial era and given the recent decrease in the emissions of sulfur in Europe and North America, O_3 is regarded as the pollutant of air potentially most detrimental to the vegetation (Matyssek et al. 2012).

On such grounds, currently, forests face significant pressures from changes in climate and the pollution in air. Until recently, global dynamic vegetation models predicted an increase in the global productivity and terrestrial sequestration of carbon in response to the climate shifts and concentration of CO_2. There have been many criticisms on these studies for over estimating the potential feedback of carbon climate because accumulation of carbon may be constrained by nutrients particularly by nitrogen (N) and by the negative impacts of increased exposure of O_3. Ozone may cause a limitation on substantial global scale by the end of this century with consequences of significant value for radiative forcing in the atmosphere by elevated levels of CO_2 (Matyssek et al. 2012).

7 Future Prospects

7.1 Synthetic Soil

In a study, the synthetic soil prepared from sand, organic material and topsoil was treated with magnetite powder for the stimulation of contaminated soil. Two soil types were chosen to prepare six soil treatments. Low contamination treatments, high contamination treatments and control. Above all, the contaminated soil had a greater decrease in the susceptibility of magnetism than the control and the difference in magnetic susceptibility (MS) decrease between the treatments was found to be statistically significant for both types of soil. Possible reasons for the overall decrease in MS were explored and among them trace uptake of elements by plants probably had a minor contribution as the differences in concentration of Fe and other trace elements (Mn, Ni) between treatments were not significant statistically. In soils, weakly or oxidized magnetic minerals, which include maghemite, hematite and goethite, were common after the growth of plants, when compared with the untreated soil. Overall decrease in MS can be contributed by transformation of minerals. The result reveals that exposure of contaminants of Fe can affect the growth of plants and suggest that growth of plant can measurably change the magnetic properties of their growth media. While thepotential variables affecting growth of plant were controlled as much as possible, but the possibility that biotic and abiotic chemical reactions could have affected the results, remains there. Thus, continuous monitoring of the changes in chemical and magnetic properties of soil in more complex soil–plant systems is required (Sapkota et al. 2012).

In soils, for the measurement of toxic metals, magnetic measurements have been used as a proxy. This may also be used to measure the sediments caused by emissions from industries. Magnetic studies of many pollutants have been studied by many researchers (Spassov et al. 2004) as well as toxic metals in polluted soils (Schmidt et al. 2005). In some of the studies, positive correlation between chemical analysis and magnetic measurement of soils and sediments have been presented, and they reveal that the concentration of magnetic minerals, that is present in the samples, exposed to toxic elements from an anthropogenic source is related to the concentration of these elements. In recent years, researchers have extended the application of methods using magnetic streaks in the study of environmental pollution by its integration with other science disciplines, which includes biological applications e.g. the bio-monitoring of air pollution traffic using the tree leaves magnetic properties, and also civil/environmental engineering applications, such as studies of building facades to measure the rates of erosion and monitoring of contamination of urban atmosphere. Microbe mediated magnetite formation was detected precisely by *in-situ* susceptibility of magnetite (Porsch et al. 2010). This study examined the potential of using magnetic methods to monitor the changes in magnetic properties of soil during the growth of plant in soil contaminated with metal and the possible use of these changes as a proxy for monitoring the uptake of toxic metals by plants. It has been found that plant species such as mustard, cucumber and dandelion are metal accumulating and they transport and concentrate metals from the polluted soil into their harvestable parts like above ground shoots and roots, in a process known as phytoextraction. Iron uptake mechanism is also observed in tomato plants. Tomato plants have also been used to understand iron deficiency stress and the metabolic response, the uptake of trace elements with time and the fly ash effect amendments in uptake of trace elements. It was noted by Jensen et al. (2004)that when the fly ash content of soil was increased, tomato plant increased the uptake of Cd, Co and Mo.

7.2 Phytoremediation

Phytoremediation is a cost effective strategy for remediation of soil polluted with heavy metals. Phytoremediation, or the use of green plants in order to clean up the polluted sites, is promising technology for cleaning up of the polluted sites with heavy metals. In some studies, phytoremediation from technical aspect together with its advantages and limitations has also been studied. Different strategies come under the term “phytoremediation” such as:

1. Phytoextraction
2. Phytostabilization
3. Phytodegradation/phytotransformation

4. Rhizofiltration/phytofiltration/blastofiltration
5. Phytovolatilization
6. Rhizoremediation/rhizodegradation/plant-assisted degradation/plant-aided *in-situ* biodegradation/phytostimulation
7. Phytosorption
8. Phtyocapping (Alkorta et al. 2010)

In case of organic pollutants, rhizoremediation appears to have increased potential because it combines plant's ability in detoxification of xenobiotics (the so-called "green liver") with the capacity of rhizosphere microorganisms in degradation of organic compounds. On the other hand, in case of heavy metals, phytostabilization and phytoextraction are the strategies of choice (Maria et al. 2012).

7.3 Activated Carbon

For improvement in the land for better production of plants, certain measures are under practice. The amendment of 2 % powder and granular activated carbon, also known as PAC and GAC, to a soil having moderate contamination of PAH had an impact on the PAH bioaccumulation of plants and earthworms, since AC is known to be a sorbent of strong nature for organic pollutants. Furthermore, AC secondary effects on the earthworms and plants were studied through the uptake of nutrient and growth as well as weight gain and survival. In addition, the effects of AC amendments on the characteristics of soil like capacity of holding water, pH and retention of water curve of soil were also studied. Results revealed that the amendment of 2 % PAC had a negative effect on the growth of plant while the increased GAC helped in the increase of plant growth rate. PAC had a toxic effect on earthworms that was demonstrated by weight loss to a significant level, while the results for GAC were less clear due to ambiguity in the result of a field and a parallel laboratory study. Both kinds of AC significantly reduced biota to soil accumulation factors (BSAFs) of PAHs in earthworms and plants. The GAC reduced the BSAFs of earthworms by an average of 47 ± 44 % and the PAC amendment reduced them by 72 ± 19 %. For the investigated plants, the BSAFs were reduced by 46 ± 36 % and 53 ± 22 % by the GAC and PAC, respectively.

8 Conclusions

Plants are the most important entities of food chain. Along with the above-mentioned pollutants, a number of other pollutants are also causing damage to the plant population either directly or indirectly. There are certain remedies to be done otherwise it will impose a negative effect on not only the plants but on humans and animals as well. The population of pollinators is also being effected. Certain measures are to be taken to decrease the concentration of heavy metals. Air and soil needs filtering agents and several check points are also required to control the immense chaos and loss being done to the plants. If this goes untreated or uncontrolled, the future of plants will be in grave danger.

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