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Repercussion of soil pollution on plants

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Abstract
Healthy environment is been established by healthy soil. But nowadays, soil pollution is becoming a major threat to environment, so we need to overcome fast. The soil is the home for a large part of bacterial biodiversity and other microscopic and macroscopic living organisms. Many of the natural processes and destructive human activities lead to the contamination of the soil where heavy metal contamination is the major issue in the environmental problems of soil. Other pollutants mainly include chemicals such as pesticides, lead, ammonia, petroleum hydrocarbons, herbicides, nitrate, naphthalene, mercury etc in an excess amount. These chemicals reduce the soil quality by hampering its fertility and further make the soil inhabitable for macro-organisms and microorganisms existing in the soil. Moreover, food security is also been hindered as soil pollution minimizes the yield and quality of the crops. This review article will brief the status of soil contamination, its origin and risks in the commencement and after effects on plants and their productivity status. Proper action is to be taken as healthy soil is considered non-renewable, precious commodity for sustainable and food protected future.

Keywords: agrochemicals, biodiversity, contamination, food security, heavy metals, soil pollution

Introduction
Pollution affects everything from the air we breathe to the food we eat. It is invisible thereby can pose serious threats and even go untraced. Presence of chemicals, pesticides, fertilizers etc. in the soil above a certain limit causes disturbance in the growth and survival of the plants and animals is known as soil pollution. Soil pollution disturbs the growth of the flora by creating various stresses. Extensive use of pesticides, herbicides and fertilizers causes depletion of soil and later on converts it into desert. Nearly, 20 million hectares of agricultural land is irrigated with untreated waste water (WHO, 2006) [101] which is also one among other sources of soil pollution. These pollutants increase the salinity of the soil and make it more redundant for the growth of the plants. This in turn causes deprivation of minerals from the soil and makes it infertile.
World population is increasing day by day whereas the productivity of the crop is not increasing in the same proportion. Pollution seriously affects soil functions, by decreasing the number and diversity of species inhabiting in the same soil. Successive decrease in the microbial activity of soil reduces nutrient cycling and in the consequence of which the soil structure gets affected and modified as well as the fertility for crop production (Jacoby *et al.*, 2017) [41]. Different types of pollutant are reported in the soil named as radioactive fallout, microbial pathogenesis, salinity and metal contaminants (FAO, 2009) [23]. Other causes include the rupture of underground storage tanks, percolation of contaminated surface water, leaching of wastes from landfills, discharge of industrial effluents into the soil, unfavorable irrigation practices, improper septic management, sewage and fuel leakages from automobiles etc. All these pollutants get washed with rain water and seep into the soil later on causing serious health concerns of plants as well as animals. Therefore, these pollutants need serious concern for their eradication from the agricultural soil. The different pollutants existing in soil and their after effects on plants are well illustrated in Fig.1. Therefore, this review provides a detailed study on the type, occurrence, causes and extent of susceptibility of pollutants.

Heavy Metals
Heavy metals are the kind of major pollutants of soil pollution as they are complex having more perseverance properties to remediate in nature. They also possess metallic properties which sum ups with malleability, conductivity, ductility, ligand specificity and cation

stability. Their atomic number is greater than 20 with relative high atomic weight (Raskin *et al*., 1994) [80]. Some metals namely Co, Fe, Mn, Cu, Mo, Ni, Zn and V are required in lesser amount to the organisms but as their amount is increased due to geologic and anthropogenic activities viz., burning of fossil fuels, mining and smelting of metals, use of fertilizers and pesticides in agriculture, production of batteries and other metal products in industries, sludge, sewage and municipal waste disposal so become considerably harmful for both the plants and animals (Alloway, 1990; Shen *et al*., 2002) [3, 86]. Some other metals are also lined up like Pb, Cd, Hg and As coming under metalloid are main threats to the plants and animals as they do not have any beneficial effects. In soil, metal exists as separate ion or in mixtures with other metals or with soil constituents. These constituents contain free metal ions, resolvable metal compounds, unresolvable inorganic metal compounds such as carbonates and phosphates in soil solutions, non-exchangeable ions and exchangeable ions which are adsorbed on the faces of inorganic solids and also metals attached to silicate minerals (Marques *et al*., 2009) [61].

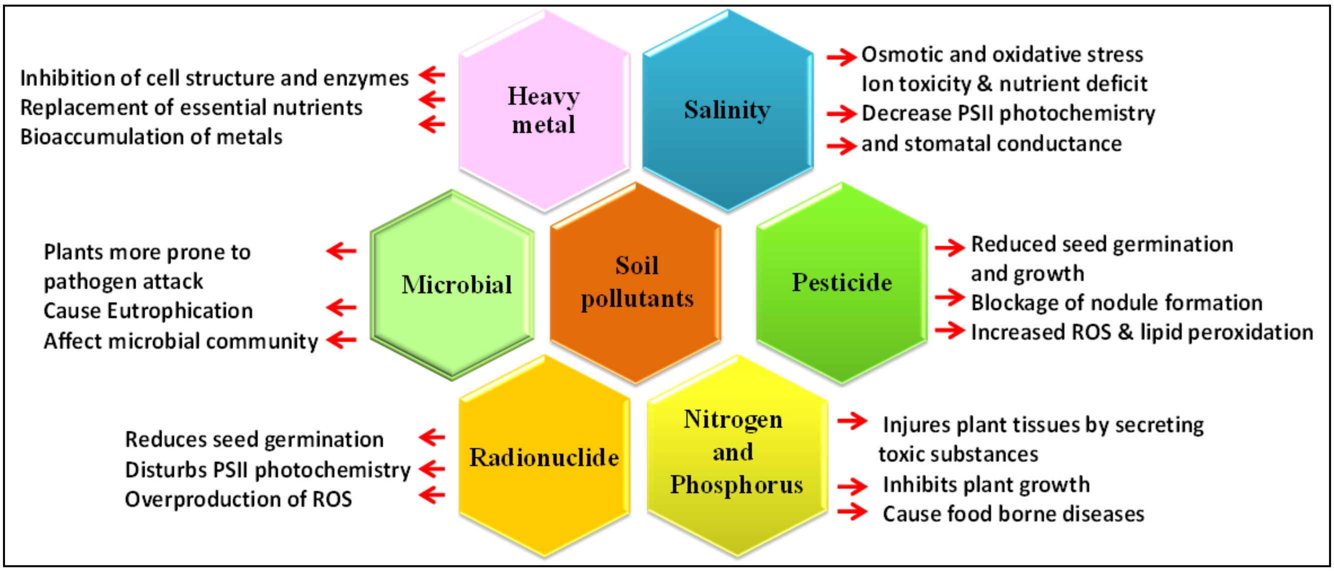

Fig 1: Different types of soil pollutants and its effects on plant physiology and metabolism

A. Heavy Metal Availability in Soil as Affected by Soil Physical Properties

It has also been noted that many of the soil properties affects diversely the availability of metal in the soil. Significantly soil pH, moisture content, water holding capacity are the main properties of soil which have positive or negative correlation with the heavy metals (Sharma and Raju 2013 [84]; Haddad *et al*., 2018 [35]; Liu *et al*., 2018) [54]. In accordance to it, in the roots of *Thlaspic aerulescens*, availability of Cd and Zn decreased with increased soil pH (Wang *et al*., 2006) [100]. Also, heavy metal availability is decreased by organic matter and hydrous ferric oxide through the process of immobilization of these metals (Yi *et al*., 2007) [103]. Conversely, heavy metals are known to modify the biological properties of soil (Friedlova, 2010) [24].

B. Heavy Metal Affects Biological Properties of Soil

The harmfulness of metal on soil microorganism depends on the various factors such as soil pH, temperature, inorganic anions and cations, organic matter, clay minerals and chemical forms of the metal (Baath, 1989 [6]; Friedlova, 2010 [24]; Haddad *et al*., 2018) [35]. Many of the studies describe the discrepancies related to heavy metal contributing soil pollution. Some of the researchers recorded positive effects while others recorded negative effects of heavy metal on biological properties of soil (Smejkalova *et al*., 2003 [92]; Castaldi *et al*., 2004 [16]; Friedlova, 2010 [24]). If one metal is present in the soil it affects the other one as well. This indicates that an antagonistic and synergistic behavior exist among heavy metals. Salgare and Acharekar (1992) [81] reported that in the presence of Cd, the inhibitory effect on the total amount of mineralized C was antagonized. Likewise, Cu and Zn as well as Ni and Cd have been testified to compete for the same membrane carriers in plants (Clarkson and Luttge, 1989) [18]. In contrast, the toxicity of Zn was increased in presence of Cu in spring barley (Luo and Rimmer, 1995) [56].

C. Heavy Metal Effects on Plants

Heavy metals which are soluble in soil solution or are solubilized by root exudate are been up-taken by the plants and affects directly as well as indirectly (Blaylock and Huang, 2000). Initially, in limited amount these heavy metals are required for their growth but above the threshold limits are toxic to the plants. Plants have the unique ability to accumulate the essential metals but this also negatively enables them to accumulate the non-essential metals (Djingova and Kuleff, 2000) [21]. In plants, the direct toxic effects with increasing concentration of heavy metals pertains to the inhibition in cell structure as well as enzymes present in the cytoplasm mainly due to induced oxidative stress (Assche and Clijster, 1990) [5]. The indirect toxic effects include the replacement of essential nutrients at cation exchange sites of plants (Taiz and Zeiger, 2002) [96].

Soil with heavy metal concentrations are further characterized by decline in soil nutrients due to decrease in decomposition of organic matter and reduction in the number of soil microorganism. These direct and indirect toxic effects ultimately leads to the destruction in plant growth which further can also lead to the death of the plant. Presence of some non-beneficial heavy metals at very low concentrations in the growth medium has adverse effects on the plants. Kibra

(2008) [52] noted that soil adulterated with 1 mg Hg/kg exerted substantial decline in height of rice plants as well as tiller and panicle construction. Similarly 5mg/L Cd in soil solution led to decline in root and shoot growth in wheat (Ahmad *et al*., 2012) [1]. The possible reasons behind the decline in growth parameters in polluted soils might be due to decrease in photosynthetic activities, plant mineral nutrition, and abridged activity of some enzymes (Kabata-Pendias, 2001) [50]. In contrast to these findings, small concentrations of these heavy metals possibly enhance the growth and development of the plant but as soon as the amount increases in soil, its positive effects get reversed. For instance, many of the researchers examined that low concentration of Co i.e. 50 mg Co/kg increase the nutrient and biochemical content, antioxidant enzyme activities while it had devastating effects on nutrient and biochemical content, antioxidant enzyme activities in plant growth with high concentrations at 100 mg Co/ kg to 250mg Co/ kg when compared to the untreated seedlings of tomato plant (Jayakumar *et al*., 2007 [47]; Jayakumar *et al*., 2008 [46]; Jayakumar *et al*., 2013) [48]. Similarly, Zn at concentration of 25 mg/L in the soil solution improved the growth and physiology of cluster beans. On contrary, 50mg Zn/L of soil solution was noted to result in starting of reduction in growth and physiology of plants (Manivasagaperumal *et al*., 2011) [59].

The sources of metal toxicity are so diverse that at times there is more than one heavy metal in the soil which affects plant toxicity in both antagonistic and synergistic relationship. One of such study was reported by Nicholls and Mal (2003) [69] where both the heavy metal Pb and Cu at their high (1000 mg/ kg each) and low concentrations (500 mg/kg) damaged vigorously the stem and leaves of *Lythrum salicaria* and ultimately lead to death. The authors analysed that there was no synergistic relationship between the heavy metals probably because the concentrations were so high to have interactive relationship among them. Ghani (2010) [30] tested the effect of six heavy metals (Cd, Cr, Co, Mn, Hg and Pb) on the growth and physiology of maize and showed existence of antagonistic relationship among the heavy metals where growth and protein content of maize seedlings was drastically reduced. The researchers were amazed on seeing the combined effect of two heavy metals as detrimental as the effect of most harmful heavy metal. The range of toxicity of these metals was in the following order: Cd > Co > Hg >Mn> Pb >Cr.

Plants also possess variety of mechanisms to avoid the toxic effects caused by heavy metals in soil. Some plants are able to tolerate the high concentrations of heavy metals in the surroundings. Baker (1981) reported three supposed mechanisms acquired by these plants to tolerate these heavy metals namely (i) exclusion- the act of not allowing metal transport to take part in an activity and conservation of a persistent metal amount in the shoot over a extensive range of soil concentrations; (ii) inclusion- maintaining the linear relationship of metal concentrations in the shoot as well as in the soil solution and (iii) Bioaccumulation- accumulation of metal of both high and low concentration in soil at a rate faster than that at which it is lost by catabolism and excretion in shoot and root of the plants.

Salinity

A. Causes and Distribution

With the onset of 21st century, it was marked largely as environmental pollution basically due to increased salinization of soil and water. Among the other environmental stressors, soil salinity is found to be most devastating in terms of destruction in cultivated land area and crop productivity and quality. With the increasing human population, there are decreasing available land area for cultivation, consequently, reduction in crop productivity which leads to the major threats, needs to be cope up for stable agricultural sustainability (Shahbaz and Ashraf, 2013) [83]. Saline soil is explained when the electrical conductivity of the saturation extract at 25 °C in the root sector exceeds 4 dSm^{-1} (approx. 40 mM NaCl) has an exchangeable sodium of 15% (Munns, 2005; Jamil *et al*., 2011) [66, 42]. Factors like low precipitation, high surface evaporation leads to extreme climate, weathering of native rocks, bad irrigation practices with saline water and poor, unaware cultural practices are held to be responsible for salinity.

Worldwide salinized region are growing at a rate of 10% annually, which by the coming year 2050, will become more than 50% of the arable land leads to low agricultural potential (Jamil *et al*., 2011) [42]. Naturally, salts are present as ions in the soil. The sources of getting salt in the soil are probably observed to be irrigation with saline water or with fertilizers, getting upward in the soil through shallow groundwater, also get accumulated under low precipitation as not able to leach ions from soil outline and causing soil salinity (Isayenkov and Maathuis, 2018) [40].

In India, saline soil covers approx. 7 million hectares of land (Patel *et al*., 2011) [76]. Most of the rejoin include indo-gangetic plane covering adjoining states like Uttar Pradesh, Bihar, Haryana and Punjab and some parts of Rajasthan. Some of the arid and semi-arid regions also get affected by saline soil which includes Gujarat, Madhya Pradesh, Maharashtra and Karnataka.

B. Effects of Salinity

Salinity disturbs the ecological balance of that region as it not only decline the agricultural productivity of crops but also have a major impact on the physico-chemical properties of soil mainly causing the soil erosion (Rahneshan *et al*., 2018) [78]. It effects seed germination, nutrient and water uptake, plant growth and reproductive development (Akbarimoghaddam *et al*., 2011) [2], causes physiological damages as ion toxicity, nutrient deficiency, osmotic, metabolic and oxidative stress, when the salt accumulation in the soil are higher than inside the root cells, the soil will draw water from the root, and the plant will wilt and die (Singh *et al*., 2019) [94]. Also, the salinity causing acidity and alkalinity of the soil due to the imbalance in pH value as a result of excess sodium may end to micronutrient scarcities (Rahneshan *et al*., 2018) [78]. With reference to salinity, plants sensitivity varies among different species as tomatoes, onions and lettuce comes under the resistant variety and on contrary, halophytes are the tolerant variety. Phosphorus uptake was considerably declined as ions of phosphates get precipitated with Ca ions (Bano and Fatima, 2009) [8]. One of the most important physiological parameter is the photosynthesis which is also damaged on account of salinity along decline in leaf area, chlorophyll content, transpiration rate and stomatal conductance and also to some extent affects the PSII photochemistry and electron transport chain (Parihar et al., 2015) [73]. It is also reported to result in impairment in the supply of photosynthetic assimilate and the regarding hormones (Ashraf and Harris, 2004 [4]; Netondo *et al*., 2004)

[68]. Plant growth development is also hampered by inhibition at the level of microsporogenesis and elongation of stamen filament during reproductive stages resulting in the enhanced ovule abortion, programmed cell death and senescence of fertilized embryos. All these factors starting from the germination to the reproductive level and finally ending towards senescence result from osmotic stress at the physiological, biochemical level and at the molecular level (Parihar *et al*., 2015 [73]; Isayenkov and Maathuis, 2018) [40]. At the molecular level, ion toxicity has been portrayed by the replacement of K^+ by Na^+ in biochemical reactions, and Na^+ and Cl^-ions persuaded conformational deviations in proteins. Biologically, inside the cell is K^+ion which is important and can't be replaced by any another ion. In the translation process a sufficient amount of K^+ion is needed for the binding of tRNA to ribosomes for protein synthesis (Zhu 2002) [107]. Prunning in spikelets per spike, stucked spike emergence and reduced fertility all at the reproductive phase was found to be more profound in the wheat seedlings exposed to 100-175 mM NaCl ultimately resulting in poor grain (Munns and Rawson 1999) [67]. So, such combined effects of salinity also damage the cell cycle and cell differentiation. Recent report confirms the effect of salinity on RNA, DNA as well as mitosis, meiosis, protein and enzymatic activity (Tabur and Demir 2010; Javid *et al.* 2011) [95, 45].

Pesticides

Pest considered an important aspect for the farmers in agriculture in both developed and developing countries. Agrochemicals were introduced to the agriculture decades ago aiming to enhance crop productivity, yield and also to protect the vegetation from weeds and pest. It has also been estimated that usable amount of pesticides which is actually used to control pest and reaches the action site is only a small part (<0.1%), and rest of the big portion is lost via run-off, foliar spray drift, photo degradation, off-target deposition (Silva *et al*., 2019) [87]. However, Joy *et al*. (2013) [49] reported that in sorghum translocation in plant and adsorption of pesticides by the soil is not justified to gain resistance. As pesticides have high persistence in the soil so in agriculture unselective and unconcerned use of these chemicals have major associated damages such as environmental pollution, pesticides residue in food, fruits, fodder, vegetables, soil etc and most importantly causing ecological imbalance and pest resurgence etc. These harmful effects are not only the outcome of chemically active ingredients and their allied impurities but also due to the solvents, emulsifiers, carriers and other elements of the articulated product. The survey created by United Nations Environment Protection in 1972 detailed that nine of the 12 most undesirable persistent organic pollutants are pesticides which are used in agriculture crop since long time and for public health related vector control program.

Pesticides are known to create damages at all stages of plant life, starting from seed germination. Rajashekar *et al*. (2012) [79] analyzed that with the increasing dose of pendamethalin in *Zea mays* L. NAAC-6002, seed germination rate reduced drastically to 69% in treated seedlings. Similarly, length of plumule decreased by 77% and the length of radical decreased up to 90% at 10 ppm. Dubey and Fulekar (2011) [22] reported that the use of chlorpyrifos, cypermethrin and fenvalerate at amount of 0-100 $mgKg^{-1}$ through spiked soil caused significant decrease in seed germination. But at higher concentrations (75 and 100 mg/kg) of chlorpyrifos, this decrease was more profound compared to cypermethrin and fenvalerate in *Cenchrussetigerus* Vahl, *Pennisetumn pedicellatum* Tan seedlings. Moore and Kroger (2010) studied the combined and single treatment effect of three insecticides and two herbicides, asfipronil showed lowest 76% seed germination, but diazinon attested well in germination (85%) which is more than the control. Among herbicides combined treatment of atrazine and metalachlor was found to have better germination rate by 85% than from the single application of atrazine which was 72% in rice seedlings. Basantani *et al*. (2011) [10] reported that the percentage of growth, root length and shoot length declined with the application of glyphosate (10mM) in two varieties of *Vigna radiata.* Similar observations were reported by Singh and Prasad (2018) [90] while studying the effect of chlorpyrifos, dimethoate and dieldrin applied twice at its recommended dose on the growth parameters of *Spinacia oleracea*. It was explained on the basis of decreased photosynthetic pigments and increase in reactive oxygen species and oxidative damages in turn. Chlorotoluron obstructed the photosynthetic electron transport in higher plants (Fuerst and Norman 1991) [27] and interrupted PSII reaction centre (Barry *et al.* 1990). Parween *et al*. (2011) [75] reported that insecticide chlorpyrifos significantly increased the plant height, total leaf area, number of branches, leaf per plant and plant biomass when applied at 0-1.5mM but as the concentration increases it had all negative impact on above parameters in *Vigna radiata* L seedlings. *Cicer arietinum* L. was severely affected by some of the insecticides such as lorsban, decis, pyrifos, karate, ripcord when applied at levels 875 mL $acre^{-1}$, 200 mL $acre^{-1}$, 1125 mL $acre^{-1}$, 250 mL $acre^{-1}$, 225 mL $acre^{-1}$ respectively at pod initiation stage and continuously sprayed for 45 days after planting. After pyrifos treatment nodulation was significantly blocked. Contrary to it, grain vintage was significantly greater as compared to other insecticide (Mahmood and Shah 2003; Khan *et al*., 2009) [57, 51]. Fungicide captan at higher concentration showed decline in photosynthetic pigments (chlorophyll *a*, *b* and carotenoids) but at lower concentration or recommended doses it increased the photosynthetic pigments in pepper leaves (Tort and Turkyilmaz, 2003). Mishra *et al*. (2008) [98, 63] reported that, photosynthetic oxygen yield, photosystem II and its chemistry, CO_2 fixation along with whole chain activities were found to decline adversely at all doses of dimethoate. Suri and Singh (2011) [94] found that after treatment of *Oryza sativa* L. seedlings with quinalphos, chlorpyriphos, methyl parathion, endosulfan, imidacloprid, and deltamethrin for three days at the interval of 10 days in the potted plant with half of the recommended doses revealed that sugar, protein and amino acid reduced in content. The amount of total phenols in leaf sheaths and blades of methyl parathion, deltamethrin, and quinalphos treated plants of the two varieties got lowered. On the other hand, chlorpyriphos and endosulfan significantly lowered or did not influence the content of reducing sugars in the leaf sheaths and leaf blades of the plants. Electrolyte leakage and lipid peroxidation are induced due to the pollutant in the environment which majorly increase the over-production of intracellular reactive oxygen species (Jan *et al*., 2012) [102]. Triazoles being a group of compound, act both as fungicide as well as plant growth regulator. On one hand it inhibited lipid membranes and electrolyte leakage in carrot plant as found in the study done by Gopi *et al*. (2007) [33] while on the other hand an increase in *Cucurbita maxima* L. seedlings under paraquat application by foliar spray (50-1000 µM) was found to behave as plant growth regulator as reported by Yoon *et al*. (2011) [104]. 2,4-dichlorophenols and pentachlorophenols are herbicides when applied in soil at 0-5 mg Kg^{-1} in *Triticum aestivum* L. resulted in increased TBARS, free phenols content and guaiacol POD activity but decreased CAT and SOD activity (Michalowicz *et al*., 2009) [62]. Moreover, in mung bean seedlings when chlorpyrifos was applied on foliar at dosage of 0.3mM showed a significant increase in the yield and its attributing characters viz. highest number of pods, number of seeds per plant and dry seed weight (Parween *et al*., 2012) [74].

Unselective use of pesticides leads to high residue levels in food. Even a tinch of level present in food becomes very dangerous for human health as it get accumulated in our adipose tissue when taken over a long period of time (Sanborn *et al*., 2004) [82]. The Maximum Residue Limits of pesticides in food intake as food morals diverge widely for the same pesticide on the same product among countries as well as with the international Codex Committee standards (Codex, 2010) [19]. However, still scientist are struggling hard to get safe level of pesticides residue in the food because many of the cell process inside the bodies work greatly with the help of chemical messengers at very small quantities in ppm or even ppb (Boobis *et al*., 2008) [12]. Dhas and Srivastava (2010) [20] studied the effect of carbaryl on brinjal fruits where they noticed that 9.93 ppm of carbaryl on 0.2% foliar spray get transferred to 11.47 ppm within a single day after treatment and made a shrinkage in residue to about 13.40 %. Therefore, studies should be undertaken on the side effects of pesticides, its persistence level in crops and its following effects on soil microbial flora, properties and associated nitrogen metabolism.

Nitrogen and Phosphorus

Nitrogen as well as phosphorus is required by the plants in huge amount. According to FAO, global consumption of fertilizers will reach to a huge amount of 200 million tons by 2018. The major countries that cover over 50 % of the fertilizers globally are the China, India and the United States of America (FAO, 2015) [24].

In most of the living structures of the cell like DNA, RNA, hormones, proteins, enzymes and vitamins, nitrogen and phosphorus are an essential component. They are available at many oxidation states both in organic and inorganic form. Through microbial activity unreactive form such as gaseous nitrogen (N_2) is assimilated, ammonium (NH^{4+}) and nitrate (NO^{3-}) forms are utilized by plants and the complex forms like nucleic acids and amino acids are required by the animals (Yaron *et al*., 2012) [102]. Phosphorus is used to transport the energy in the form of adenosine triphosphate (ATP) and is also the main macronutrient of living organisms. But when these two components are present in the excess amount in agricultural soils in form of fertilizers become pollutants and cause destruction in the environment (Carpenter *et al*., 1998 [15]; Torrent *et al*., 2007) [97]. By leaching and surface run-off these nutrients get into the groundwater and transported to the water bodies which leads to the accumulation of high nitrate content causing eutrophication which ultimately leads to the associated environmental and human health problems (Pretty *et al*., 2003; Yaron *et al*., 2012 [102]; Frumin and Gildeeva 2014) [26]. These nitrogen and phosphate fertilizers also have many heavy metals as As, Cd, Cr, Hg, Pb, and Zn which are harmful for soil as well as plants (Brevik, 2013) and when these nutrients applied in excess amount have negative effect on the yield. As nitrogen is an important constituent of chlorophyll, providing high energy for flower and bud growth, essential for the root elongation and foliage proliferation also makes plant more prone to pathogen attack. Hao *et al*. (2003) [37] reported that it affects the balance of crop nutrients. Nitrogen in high amount increases the decomposition of soil organic matter which directly affects the microbial community activities and its composition (Shen *et al*., 2010 [85]; Zhou and Zhang, 2014 [106]; Luo *et al*., 2017) [55] along with the soil salinity and acidity (Han *et al*., 2015) [36]. Singh and Ghoshal (2010) [89] found that nitrogen when applied in form of organic soil amendments in agricultural soil masks the negative effect of herbicides on soil fertility in terms of soil microbial biomass leading to considerable increase soil fertility and productivity in turn.

Radioactive Contamination

Radioactive contamination refers to the undesirable presence of radioactive elements or compounds in the biota (Smičiklas and Šljivić-Ivanovićl, 2016). The significant addition of radionuclides to the environment started with the construction and operation of nuclear reactors from 1945 onwards. Apart from the nuclear discharge, the use of fertilizers in heavy amount can deliberately affect the levels of naturally occurring radionuclides, more specifically the use of nitrogen, phosphorus and potassium. Uncontrolled exploitation of the nuclear power acts as a major source of pollution which can enter and affect the environment. The soils which are heavily contaminated with radioactive substances lose their efficiency to produce better quality crops and thus can be classified as degraded (Miura, 2016) [64]. For example the excavation and processing of uranium ore, over production and recycling of the nuclear fuels to the processing and disposal of radioactive wastes leads to heavy degradation of the agricultural land interferes with the crop productivity (Wuana and Okieimen, 2011).

The production of these radioactive wastes primarily occurs by the generation of nuclear power, various industries, medicines, agriculture system and research etc. (Ivana Smičiklas and Marija Šljivić-Ivanović, 2016). These pollutants inhibit the growth of the plant growing in the contaminated soil. Roots act as the primary target site in the translocation of these harmful radionuclides inside the plant and causes severe disturbance in the metabolism (Golmakani *et al*., 2008 [32]; Singh and Prasad, 2019) [91]. The presence of radioactive substances disturbs PSII photochemistry and enhanced production of reactive oxygen species which ultimately diminishes the overall performance of the plant leading to the decay of the plant with less crop productivity (Hong *et al*., 2019) [38]. In *Koeleria gracilis* Pers. it was studied that the frequency of aberrant cells and chromosome aberrations in the apical meristem of germinated seeds was significantly increased with respect to plants at other plots with lower levels of radioactive contamination. These results emphasize the role of radioactive contamination in the mutagenic and cytogenetic effects (Geraskin *et al*., 2013) [28].

Microbial Pollution

Pathogenic bacteria present in the soil makes the soil less inhabitable for the crops growing there (Vukicevich *et al*., 2016) [99]. Contamination of soil and crops by pathogenic agents is the effect of waste water reuse in agriculture that receives most attention from environmentalists and scientists. Discharge of effluents from municipal and industrial waste water contains a broad variety of bacteria, protozoa and viruses coming through human and animal feces and urine (Oguis *et al*., 2019) [70]. Therefore, this water acts as an agent of intestinal infection which either comes through contact or ingestion of soil or indirectly via ingestion of polluted crops (Pandey *et al*., 2014) [72]. People at high risk include farmers and their families, crop handlers, product consumers and inhabitants of the area nearby to the irrigated fields (Cifuentes *et al*., 2000 [17], Mara *et al*., 2007) [60]. Among all these groups most affected ones are agricultural workers since they are more blindly exposed to contaminated soils (WHO, 2006) [101].

Crops being sessile in nature get easily polluted due to their direct contact with waste water during irrigation (Brega *et al*., 2003) [13]. Contamination of the edible plant parts depend not only on the quality of water, but also on the quantity and the method of its application to soil and also on the type of crop i.e. the ratio of contamination with microbes varies from plants to plants (Jaramillo and Restripo, 2017). The pathogens attack the plants through various pathways (Fig. 2). When zucchini plants were spray- irrigated with waste water then the plants accumulated more pathogens on their surface rather than other crops. This in part happens due the hairy appearance and a close proximity of the plant to the soil which facilitates better attachment to pathogens (Oguis *et al*., 2019) [70]. The method of entry, translocation and survival period of the microbes inside the plant also differs (Zhang *et al*., 2009) [105]. *E. coli* can be translocated from soil to the leaves of lettuce through the root system or through wounds in vegetal tissues (Mandrell *et al*., 2011) [58]. Wounds also allow the entrance of *Salmonella* and *E. coli* to lettuce and tomato plants (Liu *et al*., 2018) [54]. The non-pathogenic *E. coli* can survive in soil for one month whereas in spinach leaves the pathogenic strain of *E. coli* O157:H7 can stay for14 days (Zhang *et al*., 2009) [105]. It is reported that survival of pathogenic bacteria can increase by internalization within the plant tissues (Lim *et al*., 2014). Similarly, it is also documented that *E. coli* can use the stomatal cavities in leaves to enter the internal structure of leaves. Inside the plant tissues, rate of survival of pathogens increase considerably since they use cellulose as their main source of carbon except few protozoans since they are larger in size than bacteria thus cannot access the internal parts of the plant; however, they can easily adhere to the surface of edible parts by the excretion of polymers which facilitate adhesion (Ojuederie and Babalola, 2017) [71].

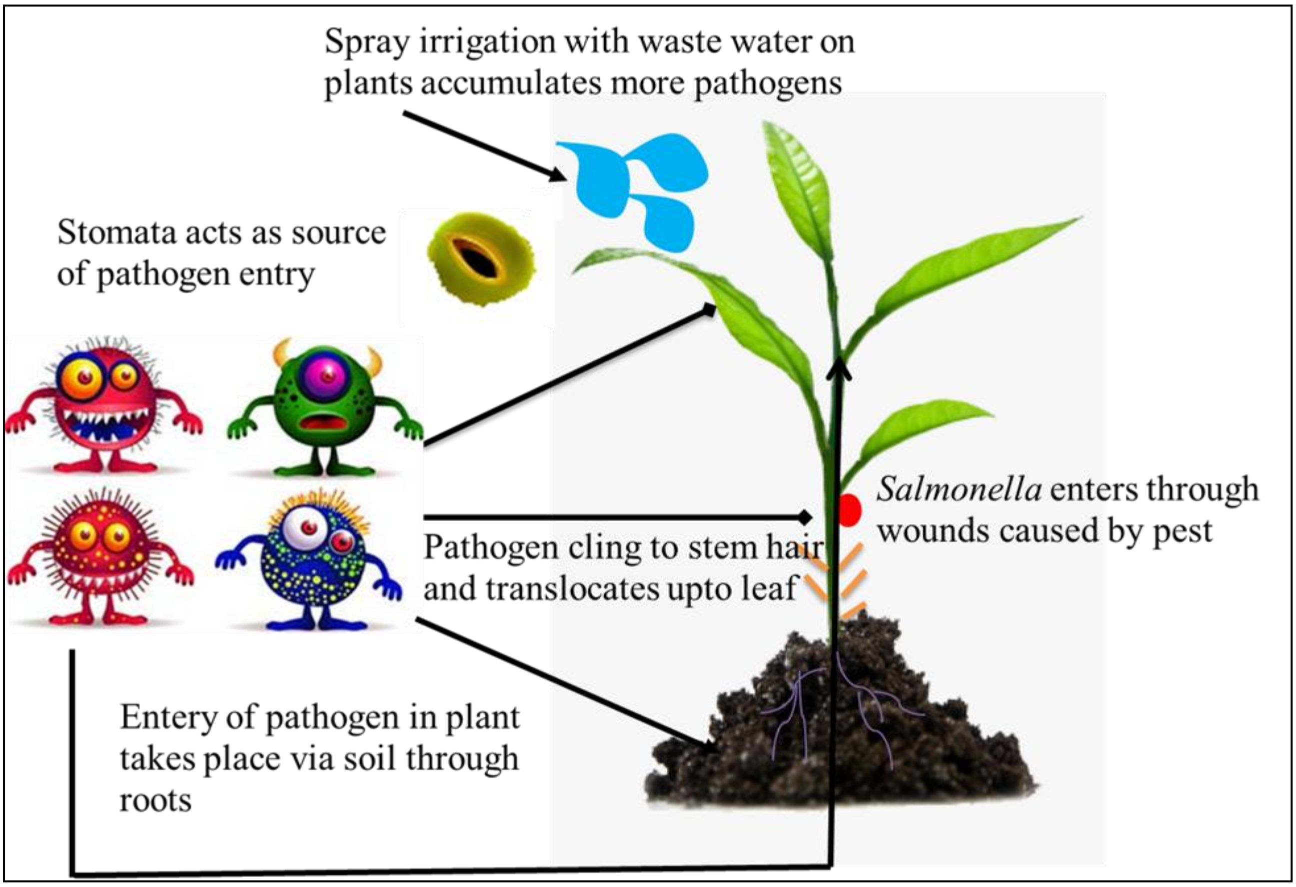

Fig 2: Sources and causes of microbial pollution in plants.

Conclusion

To meet the increasing food demands, agriculture is the best medium to work with and soil being the only medium to practice agriculture. But soil as an important part of cultivated lands is severely affected by agricultural practices. Extensive and non-proportional use of chemical fertilizers and pesticides has contributed to soil pollution which directly or indirectly affects the plant growth and metabolism. Also, soil ecosystem is hampered by the use of toxic and persistent heavy metals which had tremendously affected the soil physico-chemical and biological properties. Salt is also a major input in interfering the ionic imbalance in the plant system also damaging the soil by increasing the sodicity and alkalinity which directly hampers the overall growth and productivity of the cash crops. Soil is heavily contaminated by radioactive substances which share weaker bond with soil components that involve higher mobility of pollutant which easily get adsorbed by the biota and accumulates which enhance the level of contamination. Microbial populations constitute major shift in the structure and composition of soil properties and thereby affects functionality of soil and natural food web. Thus, these all above constituents damage the soil quality and fertility and vast biodiversity of the agricultural lands. Hence, unlike these toxic chemical inputs, cost effective and environmental friendly organic amendments must be adopted as a remedial strategy that improves the overall quality and fertility of soil which will be helpful for sustainable agricultural practices.

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