Impacts of Soil Pollution on Human Health with Special Reference to Human Physiognomy and Physiology

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Mohammed Shariq Iqbal, Zahra Iqbal, Mohammad Israil Ansari, Satarudra Prakash Singh, Brijesh Pandey, Janmejai Kumar Srivastava, and Akhilesh Kumar Singh

Abstract

Soil fulfills a wide range of ecological services such as a platform toward biomass generation, a filter/buffer for water, main store of carbon, important source of nutrients in our foodstuff as well as medicines like antibiotics and so on. However, currently, soil pollution has become one of the alarming issues in most of the developed/developing countries that is mainly contributed by anthropogenic activities like mining, smelting, manufacturing, pesticides, herbicides, etc. The rapid urbanization as well as industrialization led to enormous release of pollutants that adversely affects the characteristics of soil. Further, the nutrient inequities of soil together with the pathogenic biotic community result in undesirable impacts on human health, including plants, wildlife, and animals. In this context, concepts like soil security could offer a solution by involving multidisciplinary approaches. The amalgamation of diverse scientific and nonscientific approaches could contribute significantly towards addressing issues between soil pollution and its effect on human health, including other living organisms. Overall, this chapter is an attempt to deliver elaborate and comprehensive information on interaction between urban soil pollution and human health issues.

Keywords

Human health · Industrialization · Soil pollution · Urbanization · Xenobiotic

M. S. Iqbal · J. K. Srivastava
Amity Institute of Biotechnology, Amity University Uttar Pradesh, Lucknow, India

Z. Iqbal · M. I. Ansari
Department of Botany, University of Lucknow, Lucknow, India

S. P. Singh · B. Pandey · A. K. Singh (✉)
Department of Biotechnology, School of Life Sciences, Mahatma Gandhi Central University, Motihari, Bihar, India
e-mail: akhileshsingh@mgcub.ac.in

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10.1 Introduction

The weathering process of earth surface over the centuries has resulted in the formation of soil. Soil supports a wide range of life, from flora, fauna, to microscopic organisms. In current scenario, this important support system has been polluted with herbicides, pesticides, heavy metals, etc. which have devastating impacts on a wide range of living organisms, including health conditions, together with welfare of humans (Summers et al. 2012). Human health has been affected by soil pollutants that mainly resulted through anthropogenic activities (Rhind 2009). For instance, the soil contamination resulting in agro-lands, urban lands, lands used for extraction of oils/gases, coal mines, etc. is caused due to anthropogenic activities (Li et al. 2017). The individuals that are in direct interaction with soil (like workers in construction sites or mines, or farmers, etc.) are at severe risk of health issues as soil not only provides various nutrients for good health, but also may deliver harmful elements through the foodstuff that we eat (Chibuike and Obiora 2014). Overall, the introduction of harmful compounds into the soil causes soil pollution, which is an alarming signal for human health (Brevik 2013). Usually, the staple crops cultivated in polluted soil absorb the contaminants through vascular tissues that eventually enter the human system either through direct consumption of such crops or via the food chain (Fig. 10.1). The animals feeding on contaminated crops grown in polluted soil also negatively suffer. Soil pollutant can also infiltrate the groundwater reservoir making the drinking water unfit for consumption. The soil factors that affect human health typically involve the nature of the contaminant (severity of their toxicity), amount of contaminant in the soil, and susceptibility of the population consuming the contaminant. Few of these contaminants like herbicides, pesticides, heavy metals, etc., can be carcinogenic, while others can lead to congenital diseases, kidney malfunction, liver failure and respiratory/neurological complications. The notable relationship between soil and human health has been described in the book by Moses in 1400 BC. Further, Columella in 60 BCE remarked about unseen infections from swamplands. In each case, the concept was to indicate the significance of soil on human health. However, in 1900, the awareness about the soil interaction with humans and its impact started gaining momentum that ultimately led to worldwide acceptance for conservation of soil. It was found that the soil fertility regulates the nutrient content of staple crops, thus regulating the human health. In 1957, the United States Department of Agriculture reported that soil contamination could lead to a source of toxicity to human diet. Since then, enormous amount of literature has been gathered and cited in this particular context. To name a few, extensive work to link soil effects on human health was reported by (Voisin 1959), which was one of the novel works of that time. (Gebremedhin et al. 1990) reported about the soil pollutants and their degradation affecting soil productivity. Likewise, (Brevik and Sauer 2015) reported the effects of soil pollution on human health. With the advent of technology and recent developments in soil sciences, it has been revealed that soil contamination significantly influences human health, making it imperative for further investigation. Considering these, the present chapter provides an overview on the links between soil and its potential effects on human health.

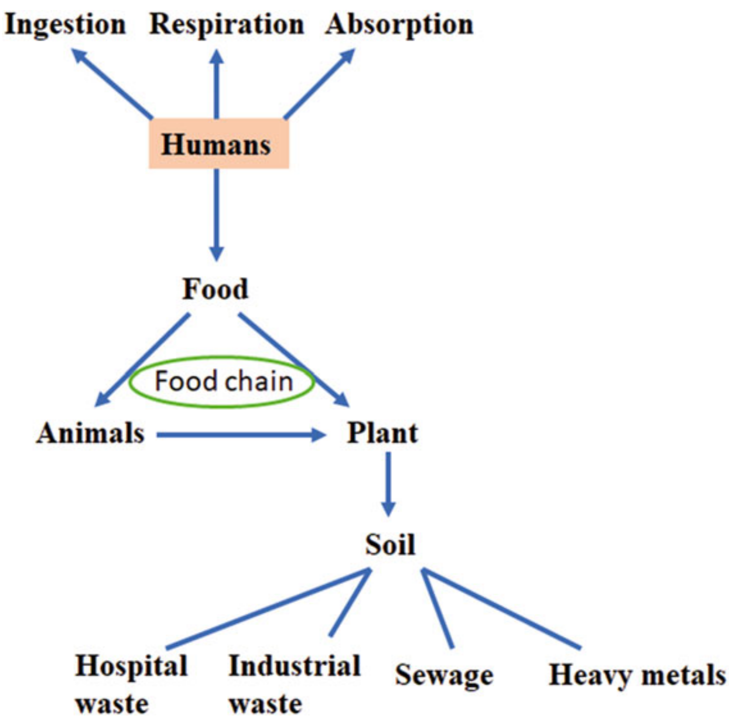

Fig. 10.1 Schematic representation of soil pollution on humans

10.2 Route of Exposure of Human Beings to Soil

Human beings are exposed to the constituents of soil (Fig. 10.2) by means of three common ways.

10.2.1 Ingestion

It may be deliberate (geophagy), accidental (contaminated hand contact with mouth), or consumption of raw vegetable and fruits without proper cleansing and washing. However, a positive aspect of consuming soil may be a supply of nutrients (rare), but the negative aspects overcome this rare bliss. Generally, the consumption of soil tends to expose the human body to heavy metals, pathogenic bacteria, and harmful chemicals. This exposure eventually results in intestinal obstruction (Henry and Cring 2013).

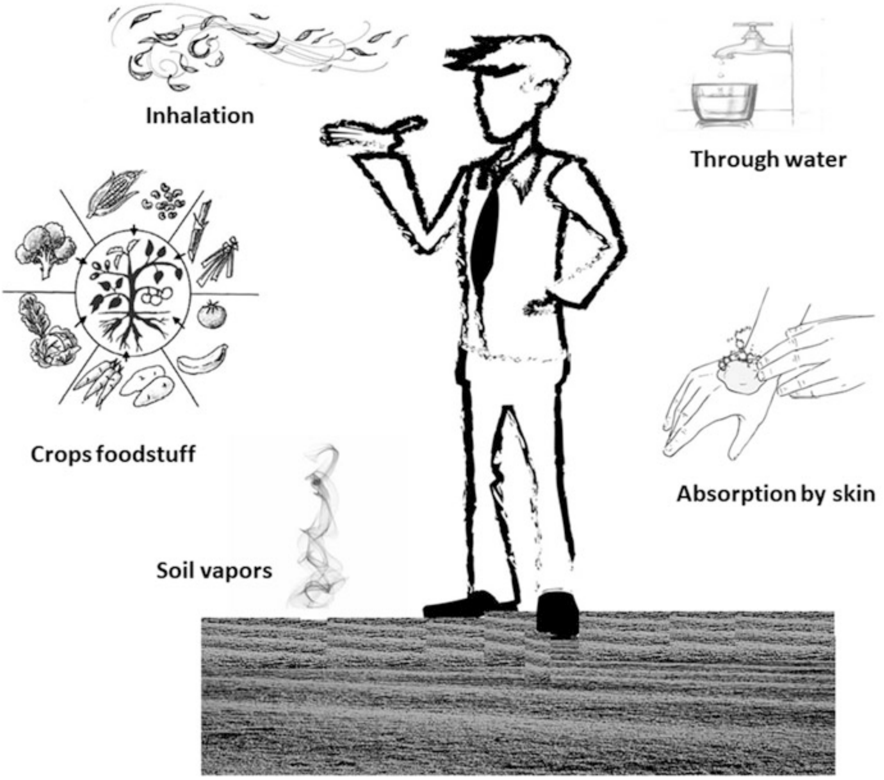

Fig. 10.2 Route of soil pollution intake by humans

10.2.2 Respiration

As the name suggests, it occurs by inhaling contaminated soil. Over prolonged periods of inhalation of contaminated soil, symptoms of coccidioidomycosis (Bultman et al. 2013; Stockamp and Thompson 2016), mesothelioma (Buck et al. 2016), bronchitis, inflammation of bronchial passage, emphysema, etc., occur in humans.

10.2.3 Skin Absorption or Permeation

It exposes humans to pathogenic microbes and harmful chemicals (Brevik 2013). It can lead to podoconiosis (non-filarial elephantiasis common in farmers exposed to volcanic clay in the soil) (Deribe et al. 2013).

10.3 Modes of Soil Contamination

10.3.1 Soil Contamination by Heavy Metals

Growing population and their anthropogenic activities has led to several fold increase in soil pollution largely through heavy metal contamination. The contaminated soil with metals, when ingested or respired in non-optimal amounts, can be of great concern. Ingestion of higher concentrations of these metals by humans can result in toxicity. Moreover, the degree of exposure is another contributing factor in determining the level of toxicity by heavy metal contamination in soil. This could result in both morbidity and mortality. Heavy metals like mercury and lead are not required by humans as nutrients, but soil contaminated with these metals can pose serious health issues even if consumed in trace concentrations (Combs et al. 2005; Brevik and Burgess 2015). Few of the heavy metals and their probable effect on human health are listed.

10.3.1.1 Lead

With the advent of industrial revolution in the eighteenth century, lead became the major contaminant worldwide through sources such as paints, Vinyl mini-blinds gasoline, mining, etc. Reports on mass lead poisoning in Senegal (Haefliger et al. 2009) by recycling of lead batteries and in Nigeria (Lo et al. 2012) by gold processing are few known examples. The ingestion or respiration of lead-contaminated soil caused severe lead poisoning, demonstrating the absolute need of awareness worldwide for soil pollution by heavy metals (Wu et al. 2015). Lead contributes to 0.6% of total world's disease. The adverse effect of lead is more pronounced on children and adolescents (Balabanova and Te 2017; Li et al. 2015). 15–20% children in USA suffer from lead toxicity because of lead-contaminated soil (Filippelli and Laidlaw 2010). Brain is most susceptible to lead contaminant. Lead can cause severe constipations, memory-based problems, headaches, sterility, tingling, behavioural issues and, in extreme case, coma and death.

10.3.1.2 Arsenic

Similar to lead, arsenic is a major contaminant in developing world. It is majorly found in drinking water from deep tube wells (Ayotte et al. 2015) and in lumber imposing serious health hazard to adults and children (Gardner et al. 2013). Arsenic toxicity also occurs via irrigation of rice fields with arsenic-contaminated water. Rice being a major staple crop worldwide results in primary arsenic exposure (Zhao et al. 2010; Kidwai et al. 2018). It generally targets vital human organs like kidney, liver, lungs, and skin. Major health concerns due to arsenic include confusion, headaches, drowsiness, diarrhoea, convulsions, excess saliva, fingernail pigmentation, cramping muscles, limb sensation, digestion issues, nervous breakdown, blood while urination, etc. Excess exposure to arsenic can also cause shock, fits, coma, and even death.

10.3.1.3 Mercury

Human activities such as gold mining, chlorine synthesis, coal burning, and dumping of compact fluorescent light bulbs contribute towards mercury contamination (Liang et al. 2015; Boerleider et al. 2017). Soil naturally contains mercury with a strong affinity for organic compounds. Microbes present in the soil methylate mercury eventually resulting in either uptake by plants or water contamination (Xu et al. 2015). Consuming sea food from methyl-mercury-contaminated water bodies and crops grown in methyl-mercury-contaminated soil are major routes for mercury hazard for human health. Hazardous effects of mercury on human health include anxiety, mood fluctuations, effects memory, depression, changes in mouth taste, vomiting, uncoordinated nervous system, respiration problems, difficulty in speaking or hearing, low IQ, delayed reflexes and in extreme exposure paralysis, stunted growth in infants, infertility, coronary heart disease, etc.

10.3.1.4 Cadmium

Yet another destructive contaminant of soil is cadmium, largely contributed through industrialization, electroplating, and sewage wastes (Nordberg et al. 2015). Exceedingly high levels of cadmium in soil can concentrate in crops consumed by humans leading to toxic effects (Hunter 2008). Its availability in soil depends upon soil pH, soil aeration, and concentrations of other metals in the soil (Zhao et al. 2014). Cadmium toxicity in humans depends upon other nutrients such as Zinc and Iron (Brevik 2013; Morgan 2012). For example, a population in England was exposed to high levels of cadmium. However, due to large Zinc concentrations in the soil, the bioavailability of cadmium remained significantly low resulting in no health hazard (Chaney 2015). On the other hand, high cadmium levels with its corresponding high bioavailability in Japan led to the outbreak of itai-itai disease (Nordberg et al. 2015). Renal, cardiovascular, and respiratory disorders are generally associated with cadmium contamination.

10.3.2 Soil Contamination by Radioactive Substances

Radioactive elements pollute soil either by natural processes or by human activities. Radon is one such natural radioactive gas that accrues in underground basements (Appleton 2007). Since it is innate to the soil and causes lung cancer (Islami et al. 2015), adequate ventilation is necessary to decrease its accumulation (Khan and Gomes 2018). Apart from this, human activities discharge radionuclides in the soil, posing a great hazard to human health. This discharge can be accidental or deliberate. Radionuclides are secondary products from hospital wastes or nuclear activities resulting from testing, fallouts, power failures, and bombing (Hu et al. 2010). Fukushima Daiichi nuclear plant disaster in Japan and Chernobyl nuclear disaster in the Ukraine (former USSR) are two major accidental anthropogenic radioactive fallouts in environment, including soil, till date that have been a serious threat to human health and well-being (Chino et al. 2011; Brevik 2013). Direct exposure to radioactive substances results in onset of cancer and genetic mutations (Magill and

Galy 2004), while indirect exposure leads to nutrient imbalances in the soil (Brevik 2013).

10.3.3 Soil Contamination by Xenobiotic Chemicals

Artificially synthesized carbon-containing compounds are termed as xenobiotic chemicals. Since these are synthesized artificially, they are unnatural. They differ from their natural counterparts in terms of insertion of chlorine, fluorine, bromine, sulphur or nitrogen (Calabrese and Baldwin 1998; Kumar et al. 2015; Sharma et al. 2016; Singh et al. 2017; Salem et al. 2017; Singh et al. 2018; Singh et al. 2019). As xenobiotics are structurally different from their natural counterparts, microbes lack the presence of biotransformation pathways to metabolize these them (Sharma et al. 2016; Singh et al. 2020). This marks xenobiotic compounds resilient towards decomposition, and therefore they are highly toxic even in trace amounts. In rural areas, pesticides impose a severe threat and contribute towards soil pollution as they reach the soil. With green revolution, the application of pesticides increased worldwide, which eventually raised its percentage in soil as well. In urban areas, soil is polluted through discharges from hospitals, industries, waste incineration, mining, coal burning and other biowastes (Leake et al. 2009). Recently, pharmaceutical and cosmetic waste from hormonal treatment, antibiotics, and injections has increased several folds contributing towards soil pollution and imposing threat to human health (Albihn 2002; Aust et al. 2008; Crofts et al. 2017). Xenobiotics are often diluted forming mixtures in the uppermost layer of the soil. Some of the xenobiotics can also be referred to as persistent organic pollutants (POPs) because they have longer half-life periods. POPs are resistant to bio-decomposition and hence eventually accumulate in higher-order food chain. One classical example is DTT (1,1,1-trichloro-2,2-bis (p-chlorophenyl) ethane). DTT is known to adversely affect the hormonal balance in raptors making the eggshell fragile to sustain chicks (Vega et al. 2007). Other xenobiotics such as polycholorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and tricholoroethylene (TCE) also possess recalcitrant properties resulting in their bioaccumulation.

Major health hazards associated with xenobiotics include (i) physical - oedema, headache, drowsiness, multiple sclerosis, rheumatism, cardiac issues, and cancer (ii) psychological - autism, anxiety, laziness, difficulty in sleep, aggression, and mental disorders.

10.3.4 Elements in Soil as Basic Nutrients

There are 14 indispensable elements necessary for plant growth and development, which are often soil-derived. These nutrients are also crucial for human health (Combs et al. 2005). Humans obtain these nutrients (macronutrients and micronutrients) through plant or animal food consumption. To sustain human health, these macro- and micronutrients are indispensable (Combs et al. 2005). Therefore, plants grown in soil with adequate nutrients are important for human health as they are either directly consumed by humans or indirectly eaten by animals, which, in turn, are food for humans. Some of the important nutrients in view of human health are as follows.

10.3.4.1 Iron

Iron is an important component of haemoglobin, which binds and releases oxygen in human body. Its deficiency is known to cause anaemia. A large population of the world is anaemic, especially women. Plants grown in soil with less iron concentrations will produce edibles with deficient iron content. In alkaline soils, plant roots are unable to absorb iron. When such plants are consumed by humans, they will consequently have lesser iron (Combs et al. 2005). Less iron will cause paleness, excessive fatigue, dizziness, shortness of breath, dry skin and hair, heart palpitations, soreness of tongue, brittle nails, etc.

10.3.4.2 Iodine

Iodine deficiency, due to iodine-deficit-soil-cultivated plants consumed by humans, largely affects brain tissues. Paucities are prevalent in regions where soil is incapable to supply optimum iodine to crops. This is common in high-altitude regions of the world (Combs et al. 2005). It is more hazardous where a large population is vegetarian. Substantial efforts have been made through “Universal Salt Iodization” to combat iodine deficiency. Health hazards due to iodine scarcity include goitre, late physical growth, hypothyroidism, miscarriage, and stillbirth.

10.3.4.3 Selenium

Selenium plays role in immunity and thyroid functioning (Fairweather-Tait et al. 2011). Its concentration varies from region to region depending upon geological, climatic and polluting factors. Thus, the bioavailability of selenium in staple crops also differs substantially (Haug et al. 2007). Humans consuming non-optimal selenium concentrations are at higher peril for cardiac diseases, tumour formation, compromised immune system, brittle nails, dull hair, nervous issues, kidney damage, lung failure, etc.

10.3.4.4 Zinc

50% of the total world’s soil is deficit of zinc. Calcareous and highly acidic soils are reported to be in maximum deficit in adequate zinc content (Abrahams 2002; Combs et al. 2005). Zinc acts an imperative component in many enzymes and co-enzymes. Its deficiency due to polluted soil grown plants can be a serious threat to human populations. It affects differentiating tissues, immunity and gastrointestinal tract, prevents healing of wounds, stunted growth, bad mouth taste, etc.

10.3.4.5 Magnesium

Similar to zinc, magnesium is also an integral part of enzymes and co-enzymes. Soil containing inadequate contents of magnesium due to contamination and/or pollution can be a potential hazard to human health and well-being. This is common in acidic, sandy and older soils of the tropical regions of the world. Its paucity leads to decrease in crop yield and quality, and makes the crops susceptible to microbial attack. Magnesium deficiency or hypomagnesemia leads to muscle twitches, osteoporosis, hypertension, asthma, cardiac problems, mental instability, etc.

10.3.4.6 Calcium

Lower calcium levels are observed in soil, which are acidic, sandy or coarse. Deprived soil moisture due to pollution and excessive use of fertilizers also cause calcium scarcity in the soil. High levels of contaminants in polluted soil convert available calcium into insoluble forms, which is futile for the plant. Consumption of such nutrient-deprived plants by humans affects their health adversely, for example, calcium deficiency in humans is related to fatigue, fragile teeth, brittle bones, osteoporosis, anxiety, cramps, stiffness, etc.

10.3.5 Microbial Growth Due to Soil Pollution and its Impact on Human Health

Soil serves as habitat for a wide spectrum of macro- and microorganisms. Discharge of pharmaceutical, medical, industrial, sewage and household wastes in soil results in growth of various deadly microbes eventually leading to outbreak of human diseases. Most of these organisms are harmless for humans; however, few of them impose severe threat to humanity depending upon the climate, susceptibility of the population, soil condition and medical aid. One such disease is Coccidioidomycosis (Valley Fever) caused by the fungus *Coccidioides* spp. The microscopic spores of the fungus present in the soil generally enter the human body via inhalation (Stockamp and Thompson 2016). The fungus multiplies and develops in saline and highly alkaline soils. *Coccidioides* reproduce and grow inside and on the upper surface of the soil. Aerosolization (mixing of the spores in the air) of the fungal spores either naturally by storms, earthquake, strong winds or anthropogenically by construction, irrigation, etc., exposes humans to this fungus. Epidemic usually breaks after torrential downpours followed by a period of drought and dry winds.

The microbial community flourishing in the soil can impact human health directly or indirectly by facilitating antibiotic resistance or itself generating antibiotics. Resistance towards antibiotic occurs when the antibiotic fails to stop bacterial growth, thus making the bacteria impervious to that particular antibiotic. Antibiotic-resistant bacteria have gained a significant attention worldwide because of the threat they impose to mankind (Tanwir and Khiyani 2011; Khan and Khan 2016). Antibiotic resistance develops because, firstly, the antibiotics are over-prescribed/non-prescribed; secondly, the patient ceases the complete course of antibiotic before the infection is cured completely. Extensive literature is available on the relationship between soil and antibiotic resistance (Adegoke et al. 2017; Nesme and Simonet 2015). Soil provides an environmental niche for development and propagation of genes coding for antibiotic resistance (Vaz-Moreira et al. 2014). Soil often supports interchange of genetic material by which antibiotic resistance in bacteria develops (Forsberg et al. 2012; Woolhouse and Ward 2013). Diverse gene pools present in the soil confer antibiotic resistance (Nesme et al. 2014). Use of fertilizer, pesticides, insecticides considerably expands the pool of antibiotic-resistant genes and species with the soil (Popowska et al. 2012; Adegoke et al. 2016). It is still decisive that this gene pool possesses direct threat to human health (Forsberg et al. 2012; Pepper 2013; Udikovic-Kolic et al. 2014). However, sharp increase in antimicrobial tolerance is indicative of the fact that it does threaten human health to some extent. Nonetheless, this increase in bacterial tolerance has paved the way for discovery of new and more potent antibiotics. On the other hand, soil also provides a medium for natural antibiotics. Under extreme climatic conditions, soil also experiences stress and seldom produces antibiotic-like substances (Swiecilo and Zych-Wezyk 2013). The bacterial population naturally present in the soil produces compounds that hinder the survival of other bacteria and actinomycetes. Teixobactin is one such recently discovered antibiotic (Ling et al. 2015).

10.4 Probable Solutions to Prevent Soil Pollution

With the advancement in medical science, most of the stated health conditions arising from nutrient deficiency or toxin intake can be treated medically. However, taking into account “prevention is better than cure,” the key causes for these medical conditions should be focused and addressed. Soil pollution accounting from various natural and anthropogenic activities should be monitored and controlled to reduce its disastrous impact on human health. It is less expensive to prevent soil pollution than to manage it. Hence, new soil should be protected for soil pollution. The practice of “three R,” namely, “reduce, recycle and reuse” has recently gained momentum throughout the world to combat soil pollution. The reduction in usage of chemical-based pesticides, herbicides and fertilizers in agricultural practices can also be useful in combating soil pollution. Educating people and spreading awareness for the use of biodegradable products can also reduce soil pollution to several folds. To restore and maintain soil fertility the use of bio-fertilizers should be prompted by government agencies to the farmers. Providing bio-fertilizers for their chemical counterparts at a competitive price can encourage farmers to use them. The microbes present in these fertilizers will contribute towards soil fertility. Similarly, the usage of bio-pesticide and bio-herbicides on a large scale in rural areas can manage soil quality. These products definitely take a bit longer time to deliver the desired results, but to not impose a threat to the soil quality and fertility. Substituting chemical pesticides and fertilizers with manure can also help in maintaining soil integrity. Recycling wastes, especially household trash, can contribute to declining soil pollution due to landfills. Reusable materials should be made popular amongst masses to minimize the usage of plastic. Plastic disintegrates at a very slow rate or does not at all disintegrate, thus disturbing the soil harmony. In a similar vein, the use of paper should also be monitored strategically. Treating industrial waste to reduce or destroy its toxicity before disposal is necessary to eliminate soil pollution and, thus its devastating effects on human health. Responsible methods should be undertaken to dispose of the waste so that no soil contamination occurs. Consumption of organic food can help reduce the risk of deficiency of various vital elements, thus improving human health. Dumping grounds should be far from residential areas so that contaminated soil is not inhaled or ingested by humans. Moreover, several creatures thrive well underneath the soil. Disrupting their habitat could expose them to the danger to extension. Few of these organisms, microorganisms are pivotal to human health. For example, nitrogen-fixing bacteria maintain soil fertility, plant growth and yield, thus affecting human well-being. Sensible efforts should be made not to disturb this beneficial harmony. Further, to curb the disaster of soil pollution, rapid and efficient deforestation procedures have to be undertaken. The effect of soil erosion by strong winds and heavy rainfall multiplies when there no trees to impede the top layer of soil. Efforts should also be made religiously to circumvent over-cropping and grazing, since it leads to floods and soil erosion, thus relapsing the soil integrity.

10.5 Conclusion

Soil is a heterogeneous mixture that is strongly managed by natural and human activities. The anthropogenic activities accounting for heterogeneity of the soil discharge plethora of contaminants, which negatively impacts human health. Animals grazing on plants grown in polluted soil also accumulate these contaminants. As a part of food chain, humans feeding on these animals accrue toxins, which adversely affect their health. Combustion of petrol, usage of lead paints, industrialization, hospital and sewage wastes account for the major reasons of soil contamination and pollution. Although soil pollution has been controlled to some extent in developed countries, it still seems to be a life-threatening issue in developing world. Urbanization is yet another major factor contributing to soil pollution. The risk of soil-borne diseases increases proportionally with large populations shifting towards urbanization. With advancing compromise of human health due to soil pollution, enormous social, economic and political efforts are being made throughout the world by various organizations to improve soil quality. More interdisciplinary and transdisciplinary research and awareness in the coming years is necessary to fully comprehend the effect of polluted soil on human health. Political organizations should come forward to offer funding for carrying research to mitigate soil pollution. Moreover, general public should be educated and made aware of the health hazards they would face if they continue to pollute soil. People should also be made conscious towards the effort they should make to reduce soil pollution on a daily basis.

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