# Plant Responses to Sewage Pollution

# 6

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**Abstract**

Sewage is the term used for waste water that often contains faeces, urine and laundry waste. The volume of sewage in the world is increasing in leaps and bounds together with the increasing population of the world. So, sewage pollution has become a major problem throughout the world. But the situation is particularly acute in developing countries due to exponential growth of population, urbanization and lack of technical development in these countries. It is important to highlight that although Antarctica has no native human population, yet, unprocessed sewage effluents from various research stations have been reported to cause negative effects on local wildlife of terrestrial and aquatic habitats. Sewage sludge contains excess of nutrients (nitrates, phosphates, organic matter) and heavy metals, which cause eutrophication in water bodies with subsequent increase in algal biomass, primary production and decrease in dissolved oxygen. The over-populating algae and bacteria use up most of the dissolved oxygen of water, making it difficult for other aquatic organisms to live. There are positive as well as negative responses of plants to the sewage effluents. Research shows that low and moderate concentration of sewage irrigation causes stimulated seed germination and seedling growth together with an increase in pigments synthesis, carbohydrates and nucleic acids synthesis. On the contrary, studies reveal that high dose of heavy metal concentration for plants via sewage irrigation/sewage sludge-amended soil caused inauspicious alterations in physiological and biochemical characteristics of plants like a decline in biomass and yield. Furthermore, continuous sewage irrigation in cropland leads to uninterrupted supply of minerals and nutrients resulting in adverse effects on yield quality and biomass due to oxidative damage and risks of plants to counteract stress factors. The plant either becomes toxic to its consumer or it dies from the mineral toxicity. Many

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plant species provide remedies to the sewage pollution by phytoremediation and this is a cost-effective method for sewage treatment.

**Keywords**

Sewage pollution · Sludge · Sewage effluents · Eutrophication · Heavy metal toxicity

## 6.1 Introduction

Water is one of the most vital substances on the earth. According to the United Nations, more than 80% of the world's waste water flows back into the environment without being treated. Sewage pollution is one of the biggest contributors to water pollution. It has become a major problem throughout the world. But the situation is particularly acute in developing countries, especially in slum areas due to exponential growth of population, urbanization and lack of technical development in these countries. At the same time, there are many countries which utilize sewage for farming purpose. Waste water is used by farmers in regions facing water scarcity even in developed countries of North America and Europe on a large scale. For example, according to the reports of CEU (1999), about 40% of the whole sewage sludge is utilized for agricultural and farming purposes in the European Union. Reports suggest that in the year 2010, countries like Belgium, Spain, Denmark, Ireland, France and the United Kingdom used more than 50% of sewage sludge for agriculture (Kacprzak et al. 2017). Numerous studies suggested a positive effect of sewage sludge application on crops like barley (Pasqualone et al. 2017), spinach (Bravo-Martín-Consuegra et al. 2016), bean (Zeid and Abou el Ghate 2007), etc. Studies suggest that sewage sludge is very useful not only for agricultural and farming purposes, but also for irrigating forest land including *Larix deciduas* (Bourioug et al. 2014). Thus, use of sewage sludge as a cheap and easily available means of irrigation for croplands and forests has continuously been increasing steadily over the years.

The term sewage in a layman's language is generally applied for urine and faecal waste from humans. But it is actually a wide-ranging term which encompasses animal wastes as well. Sewage is not made up of a single compound; instead, it is an amalgamation of various liquid and solid substances viz. liquids including by-products of waste water treatment and solids like a mixture of inorganic substances (grit, salt and metal) and organic substances (proteins, carbohydrates, fats and biological organisms like pathogenic, non-pathogenic bacteria and viruses). Sewage can be released in the form of treated and untreated sewage. There are many point sources (viz. municipal waste water treatment plants) and non-point sources (viz. pollutants released in a large area like City Street storm run-off) for the discharge of sewage.

Sewage sludge (also known as Biosolids) is rich in macronutrients like nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sulphur (S) and magnesium (Mg), and few micronutrients. Sustainable utilization of these nutrients is used as soil improvement because biosolids are rich in important compounds and can thus be utilized for environmental potential enhancement (Londoño et al. 2017). The availability of nitrogen and phosphorus is limiting in terrestrial ecosystem (Batterman et al. 2013). Thus, sewage application to terrestrial agricultural lands may enhance the productivity of plants (Colón et al. 2017). Availability of nitrogen is more dependent on sludge treatment. Even untreated liquid sludge releases nitrogen, which gradually proves to be beneficial for the crop. Aerobically digested sludge has high contents of ammonia, which again is readily available to plants. Thus, sewage sludge is a nutrient-enriched fertilizer (Csattho 1994). Nitrogen present in sludge is likely to cause very less ground water pollution as compared with chemical fertilizers like urea (Long 2001). Therefore, sewage sludge may possibly be considered as a significant biological resource for agriculture and can be used as organic manure (Tsadilas et al. 1995; Tester 1990).

The greatest concern about the use of sewage as organic manure on terrestrial land is that its continued use may increase the risk of exposure to pollutants (e.g. heavy metals like Cd, Cu, Ni, Pb, Zn, Hg, Cr, etc.) and pathogens to plants and crops. Heavy metals on being introduced into the food chain show bioaccumulation. As discussed earlier, sewage sludge contains valuable components like organic matter, nitrogen (N), phosphorus (P), and rate of nutrient recycling is very slow. On the contrary, disposal of sewage sludge in aquatic ecosystems (oceans, lakes, ponds, etc.) causes various environmental threats (O'Sullivan 1971) like eutrophication and coral reef deterioration (Wear and Thurber 2015). For this, London Convention 96 Protocol was adopted, which prohibits sewage sludge discharge in oceans.

## 6.2 Composition of Sewage

As we have already discussed, sewage is an amalgamation of various abiotic and biotic compounds like:

### 6.2.1 Nutrients

Sewage water contains a very huge amount of inorganic nutrients, like nitrite, ammonium, nitrate, phosphate, etc. Nutrient enrichment enhances macro and micro algal growth causing algal bloom with the ultimate impact being extinction of native species (Wear and Thurber 2015).

### 6.2.2 Suspended Solids

Sewage consists of a high amount of suspended solids and most of the parts are made up of organic matter. Suspended solids enhance turbidity and hamper sunlight penetration (Rogers 1990; Tomascik and Sander 1985; Lewis 1997). Rate of sedimentation may also increase with sewage effluent discharge; simultaneously, storm events also occur (Reopanichkul et al. 2009), which cause physical stress. In addition, suspended solids also cause chemical stress because sewage effluents have a broad range of compounds with different chemical composition. Chemical inputs mainly from agricultural surface run-off (containing fertilizers, pesticides, herbicides, etc.) and natural soil erosion (containing organic matter and nutrients) (Pastorok and Bilyard 1985) in suspended solids may have toxic compounds and high levels of nutrients (Islam and Tanaka 2004; Johannes 1975). The organic compounds in sewage discharge enhance the biological oxygen demand (BOD) of polluted water via sewage. With an increase in BOD, there is a simultaneous increase in the population of microorganisms to utilize these organic compounds (Islam and Tanaka 2004; Johannes, 1975).

### 6.2.3 Pathogens

Sewage discharge has been recognized as the reservoir of the pathogen complex that can be responsible for various diseases (National Institutes of Health 2007). Sutherland et al. (2011) reported that sewage was the source of infection and disease, and that anthropogenic strain of the pathogen was the contributory driving force. This study was the first report for the transmission of an anthropogenic pathogen to the sea invertebrate sands; it gave strong confirmation for the connection between sewage discharge and disease in the sea atmosphere (Sutherland et al. 2011). This study presented that sewage is a big disease pool and that microorganisms such as bacteria and viruses present in the human gut are more common in sewage discharge. Sewage is the major cause of various health problems and most common diseases are like cholera, diarrhoea and typhoid fever (Griffin et al. 1999; Wetz et al. 2004 and Blinkova et al. 2009).

### 6.2.4 Heavy Metals

Heavy metals are usually found in sewage discharge (Grillo et al. 2001). Metals commonly present in sewage effluents consist of Zn, Pb, Cd, Hg, Cr, Co, Cu, Ni and Fe (Ščančar et al. 2000; Grillo et al. 2001). Normally, the enhancement of heavy metals leads to changes in metabolic activity as they are accumulated in the tissues of organisms. In addition to this, they also influence the bioactivity of enzymes and modify certain crucial physiological activities (Oves et al. 2016).

### 6.2.5 Toxic Compounds

An array of toxic compounds found in sewage discharge cause potential toxicity (Daughton and Ternes 1999). Toxin types occurring in sewage are dependent upon the local atmosphere; for example, the presence and kind of industries and agriculture. Chemicals like chlorine, polychlorinated biphenyls, petroleum hydrocarbons, pesticides, herbicides and products of pharmaceuticals, which are also commonly present in sewage (Pastorok and Bilyard 1985; Daughton and Ternes 1999; Islam and Tanaka 2004; Weigel et al. 2004; Fang et al. 2012).

## 6.3 Problems Associated with Sewage Pollution

### 6.3.1 Bioaccumulation of Heavy Metals

Sewage sludge application to soil has been vulnerable because of the heavy metal accumulation in soils and plants (Singh and Agrawal 2007).

### 6.3.2 Eutrophication

Nitrogen is not a limiting factor in aquatic ecosystems but this is somewhat true for fresh water and tropical water bodies. Nitrogen has been enhanced in sewage-polluted waters (oligotrophic water) in temperate regions leading to increased phytoplankton production (Khan and Ansari 2005). Various environmental factors like $CO_2$ concentration, temperature, pH, amount of dissolved oxygen, light intensity, etc. work as additives to the problem of eutrophication. The result of eutrophication is decrease in dissolved oxygen content and ultimately resulting in algal bloom formation. Other than this, the literature suggested that algal bloom also affected marshland plants and increased the rate of natural succession relatively more rapidly (Khan and Ansari 2005). There are many plant species which have been identified as best indicators of various stages of eutrophication; for example, phanerogam plants like *Potamogeton pectinatus* and *Myriophyllum spicatum* largely grow in eutrophic areas so that these plant species are regarded as tolerant for eutrophication (Wallentiuns 1979; Selig et al. 2007).

Many countries use sufficient managing strategies to control eutrophication and algal bloom. But these strategies are only partially useful in controlling the phosphorus unloading in water bodies (Khan and Ansari 2005).

### 6.3.3 Negative Impact on Local Wildlife

Sewage also influences local wildlife or change in their diversity or composition. It is important to emphasize that the entire world is facing the issue of sewage water problem. Antarctica, where there is no native human population, yet, unprocessed sewage effluents from various research stations have been reported to cause negative effects on local wildlife of terrestrial and aquatic habitats. Waste water of Antarctic research stations is a combination of human, domestic and industrial wastes released from laboratories. Waste water discharge has properties like municipal waste water although it is extra concentrated because of limited water supply. Treatment of waste water tries to decrease the amount of nutrients to avoid eutrophication of coastal water bodies. But in Antarctica due to limited water supply, treatment is a very difficult task that creates serious environmental threats like various metal and organic contaminants (Stark et al. 2015). Other than this, waste water in Antarctica has a huge number of pathogenic and non-pathogenic microorganisms, which are non-native to this region and survive in the coastal region of Antarctica (Smith and Riddle 2009). These non-native microbes may be causes of gene transfer, which lead to genetic pollution (Hernández et al. 2012). Various treatment processes are used in Antarctic stations; however, many of them are not competent enough for ameliorating the threat of waste water (Gröndahl et al. 2009; Stark et al. 2015).

In a study, 149 secondary sewage treatments were introduced at various locations of Virginia, Maryland and Pennsylvania. Presence of such a large number of sewage treatment plants led to accumulation of high amount of chlorine and turbidity, which caused reduction in diversity of fish species beneath the outfalls (Tsai 1973).

### 6.3.4 Coral Bleaching

Reports suggest that one of the major contributors to coastal pollution is sewage (Doty 1969; Banner 1974; Pastorok and Bilyard 1985; Islam and Tanaka 2004). Many coral reefs are situated by the side of the costal lines of developing countries, where sewage entering into oceans is completely unprocessed or inadequately treated. Tertiary sewage treatment in this zone is very uncommon (UNEP 1994; Islam and Tanaka 2004)**.** Most of the studies suggested that sewage effluents shave a destructive impact on coral reefs in the form of nutrient enrichment. Particularly, inorganic nutrient enrichment is the main cause of faster rate of algal growth and this is the main factor for coral diseases (Fabricius et al. 2005; Vega Thurber et al. 2014). For example, reports as early as 1996 by Marubini and Davies and later by Wooldridge (2009) clearly report that nutrient enrichment causes damage to the coral via acting on *Symbiodinium* (a symbiotic algal partner performing photosynthesis in corals). Nutrients can enhance the symbiont density that leads to parallel boost in reactive oxygen species, which possibly will result in damage to host cells that may lead to death and exclusion of the symbiont (Lesser 1996). Other than nutrients, various studies suggested that introduction of heavy metal with increasing concentration can cause coral bleaching, mortality and decreased fertilization success (Howard and Brown 1984; Reichelt-Brushett and Harrison 1999).

## 6.4 Sewage: A Double-Edged Sword

The demand for potable water is increasing continuously with an increase in population. This results in setting up of an increasing number of sewage treatment plants causing more and more water pollution. This can be explained as follows - to meet the Millennium Development Goals (MDGs), sustainable use of water and

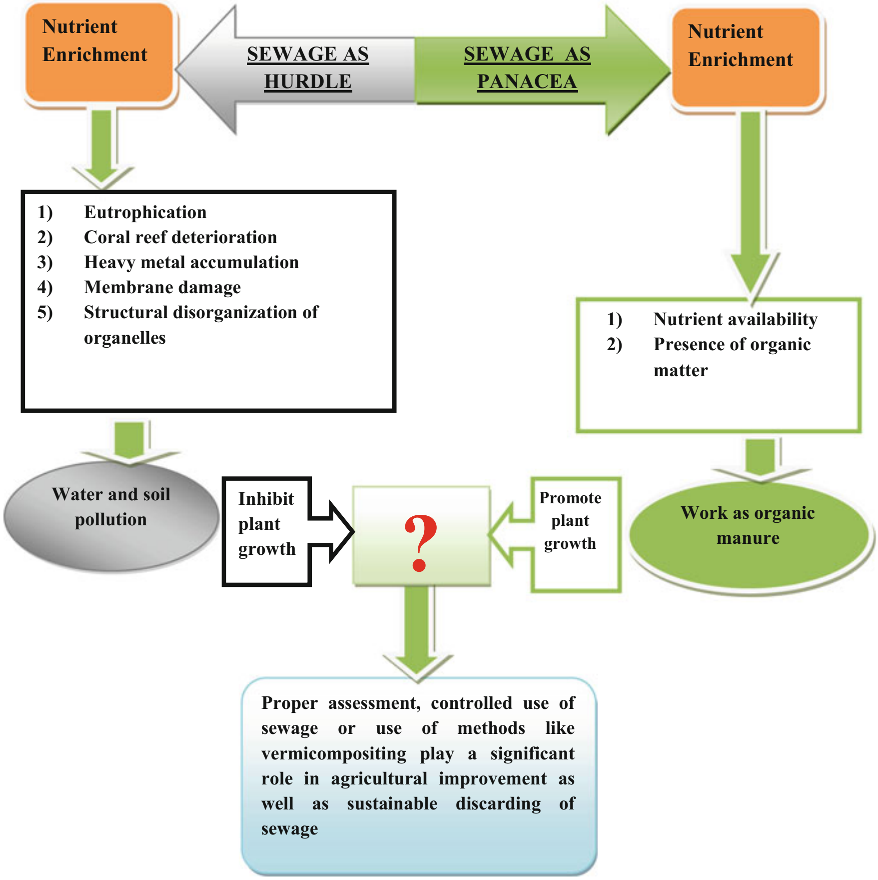


**Fig. 6.1** Distinct aspects of sewage

sanitation infrastructure and sewage treatment is required. Sewage treatment plants are a main source of pollution, contributing to various pollutants found in water bodies. Ground water also is at a risk of being polluted from immobile effluents leaking from these treatment plants. Other than pollution problems, sewage introduces a broad range of potentially infectious agents to water that may be consumed by the biotic communities, therefore, leading to increased outbreaks of waterborne diseases with significant future socio-economic implications (Fig. 6.1) (Craun 1991). Sewage is a major contributor to health issues like cholera, diarrhoea and typhoid fever (Griffin et al. 1999; Wetz et al. 2004 and Blinkova et al. 2009). Sewage effluent discharges were killing a large population of fish and destabilizing aquatic ecosystems (Mema 2010). Use of fertilizers for vegetation and agriculture proves to be an expensive method. On the contrary, the application of sewage sludge in agricultural land is the most economic, cost-effective and environmentally sustainable way (Kacprzak et al. 2017). Sewage waste water is normally used for irrigation in various developed countries viz. France, Denmark and Spain (Kacprzak et al. 2017) and also in developing countries like India (Sharma et al. 2007). Sewage is either released from treatment plants or from various point and non-point sources. Use of sewage sludge in agriculture is a global practice and is one of the most efficient and economic sludge disposal methods. Various studies suggested the positive effect of sewage sludge application on crops including spinach (Bravo-Martín-Consuegra et al. 2016) and barley (Pasqualone et al. 2017). Uninterrupted supply of sewage waste water for irrigation causes nutrient enrichment of soil through various macro and micronutrients, which is essential for plants (Das and Kau 1992; Kannan et al. 2005). Micronutrients promote the growth and metabolism of the plants but nutrients also turn out to be toxic if present in surplus than the necessity. Most of the micronutrients are heavy metals and well known to generate adverse effects on plants if they are present in surplus (Kocak et al. 2005). High amount of heavy metals causes stress-like conditions in the plant and interrupt metabolic and physiological functioning. Heavy metals cause membrane damage, structural disorganization of organelles and destruction in the physiological functioning, which finally hinders the growth of the plants (Kimbrough et al. 1999; Chien and Kao 2000; Zhang et al. 2002; Long 2001). Heavy metals enhance reactive oxygen species (ROS) generation, for example, hydrogen peroxide ($H_2O_2$), superoxide radicals and hydroxyl radicals. They transfer electrons involving metal cations or by inhibiting the metabolic reactions controlled by metals (Stohs and Bagchi 1995; Verma and Dubey 2001). In this sequence, plant endures stress condition, because they have antioxidants to remove ROS and free radicals (Gratão et al. 2005).

## 6.5 Responses of Plants to Sewage

The overall response of plants to sewage treatment is studied by analysing the following parameters:

- **Morphological responses** - growth and biomass studies like root length, shoot length,
  fresh weight, dry weight, leaf area, leaf size, etc.
- **Physiological responses** - include pigment content, alteration in metabolic activities of plants like photosynthesis, respiration, etc., and.
- **Ecological responses -** include alteration in antioxidant activity of plants, heavy metal accumulation in soil and various plant parts, etc.

Composting is suggested as an extremely suitable method to reprocess, recycle and reuse sewage sludge (Song and Lee 2010). Composting is a controlled biological method that is used to treat organic matter using microorganisms at temperatures less than 40–50 °C (Environmental Protection Agency 2006). Compost consisting sewage sludge is a proper solution for increasing the quality of soil. Thus, it is significant to study the impact of compost consisting sewage sludge on plants. In this context, various compost containing sewage sludge application studies on sawtooth oak (*Quercus acutissima*) and Japanese red pine (*Pinus densiflora*) have been performed. These studies illustrate that compost noticeably increases moisture and nitrogen content in the soil. With this observation, significant concomitant increase in plant height, biomass, nitrogen and chlorophyll content in leaves has also been reported as compared with control. As chlorophyll content increases, the rate of photosynthesis is automatically increased (Song and Lee 2010). Richard et al. (1998) found that after long-term field studies of sewage sludge application (20 years), accumulation of metals in soils were significantly increased as compared with control. Sewage sludge application also resulted in an increase in Zn, Cd, Cu and Ni concentration in grass-growing plot. As discussed earlier, sewage sludge improvement increases the concentration of heavy metal, organic matter and nutrients in soil. Organic matter reduces the pH of soil. A study suggests that sunflower (*Helianthus annuus*) has the capability to endure heavy metal toxicity (Elloumi et al. 2016). Sunflower roots accumulate a considerable amount of heavy metal and have the ability to translocate it into shoot. Thus, sunflower might be used in phytoremediation and accumulation of heavy metal was more in root tissues as compared with shoot tissues. (Elloumi et al. 2016) Sewage sludge application enhances morphological and physiological responses of sunflower like root-shoot length, number of leaves, antioxidant activity, glutathione, proline content, soluble sugar and biomass. This is due to induction of better defence mechanism induced in response to sewage sludge application and heavy metal stress (Elloumi et al. 2016). Labrecque et al. (1997) suggested that sludge possibly could be used as organic manure/fertilizer for improvement of quality of forest soils. To support this hypothesis, a study was conducted on small saplings (one-year-old) of *Eucalyptus camaldulensis* in which plants were treated with urban sludge together with soil. The amount of sludge content was gradually increased in pots. After 6 months of study, height, diameter at mid-height, base diameter and the number of leaves showed positive results to sludge application. A considerable variation was also reported in stem length and number of leaves in plants treated with sludge as compared with control. The growth enhancement was due to fast nutrient utilization (Labrecque et al. 1997). Bourioug et al. (2014) demonstrated good growth of larch (*Larix decidua*) on forest soil fertilized with municipal sludge, considered as a source of fertilizer due to its high content of organic matter and available nitrogen and phosphorus. In this study, he found limited absorption of the heavy metals via plants. Similar to the above studies, Table 6.1 shows responses of various plants to sewage or sludge application:

With sewage sludge application, a long-term study was conducted. Field studies extending over 2 years (Qiong et al. 2012) and 5 years (Li 2012) duration revealed little dissimilarity in heavy metal accumulation in soils. In a 2-year field study, the concentration of Cu, Cd and Zn were found to increase linearly in soil together with an increase in sewage sludge application. On the other hand, in a 5-year field study, Hg concentration was reported to increase in soil besides Cu, Cd and Zn. Similarly, accumulation along with translocation of such metal contaminants from sewage sludge in plant parts also shows variation (Yang et al. 2018). Thus, long-term studies are required to show the accumulation and bioavailability of heavy metals released

**Table 6.1** Various responses of plants to the sewage or sewage sludge application.

| Plant name | Effect | References |
|---|---|---|
| *Phaseolus vulgaris* (Bean) | 1. Increased germination percentage and shoot and root lengths, fresh and dry masses.<br>2. Increased yield criteria like number of pods/plant, length of pods, fresh and dry weights of pods. | Zeid & Abou el Ghate (2007) |
| *Eucalyptus camaldulensis* (One year old saplings) | 1. Increment in height and number of leaves.<br>2. Decrease in diameter of stem | Leila et al. (2017) |
| *Larix decidua* (Larch seedlings) | 1. Activity of Nitrate reductase decreases as increasing sludge application rates.<br>2. Sewage sludge did not influence larch seedling growth (after 6 week). | Bourioug et al. (2014) |
| *Beta vulgaris* (Palak) | 1. Positive effect on physiological, biochemical and growth characteristics.<br>2. Biomass and Yield did not change. | Singh and Agrawal (2010) |
| *Helianthus annuus* (sunflower) | 1. Increase in root and shoot length, leaves number, biomass, and antioxidant activities | Elloumi et al. (2016) |
| *Salix viminalis L.* (willow plants) | 1. Great increase of biomass and plant growth in small waste water treatment plant.<br>2. Efficient performance of the antioxidant system. | Wyrwicka and Urbaniak (2018) |
| *Solanum tuberosum* (Potato) | 1. Increased the concentrations of some potentially toxic trace elements in potato leaves and tubers (enhancement was normally elevated in leaves than in tubers) | Brar et al. (2000) |

by sewage sludge. In this sequence, a most recent long-term field study of 10 years with a wheat–maize crop alteration was done (Yang et al. 2018). The study was useful to consider the accumulation and bioavailability of heavy metals in soil containing adequate free calcium carbonate ($CaCO_3$). Sewage sludge was applied at various rates and accumulation of heavy metals in wheat was reported to be larger than that in maize. This study suggested that maize is more tolerant than wheat to heavy metals. This conclusion might be useful for the calcareous soil improvement via sewage sludge application (Yang et al. 2018).

In a study, palak (*Beta vulgaris* L. var. All green H1) is irrigated with waste water as compared with ground water. Uninterrupted supply of waste water via irrigation increases the nutrient concentration. According to this study, irrigation with waste water positively changes the physiological, biochemical and growth characteristics of plants, whereas biomass and yield did not differ considerably between waste water-irrigated site and ground water-irrigated site. Uptake and translocation ratio of heavy metals were higher in plants grown at waste water-irrigated site. The observed maximum uptake was of Mn followed by Zn, Cu, Pb, Ni, Cr and Cd. Plants produced more secondary metabolites and antioxidants to tolerate the negative impact of heavy metals at waste water-irrigated sites. Simultaneously, plants also produced more metabolites to compensate the toxicity of metals in the area and thus did not enhance the yield and biomass potential. So, reports suggest that plants growing in waste water-irrigated land have potentially developed the defence strategy to fight against heavy metal toxicity (Singh and Agrawal 2010). Greenhouse and field experiment studies also show variation in heavy metal content with sewage sludge application. Singh and Agrawal (2007, 2010) reported considerably increased amount of heavy metals like Cu, Zn, Cr, Cd, Pb and Ni in soil and plants. They also observed enhancement of Ni, Cd and Zn concentration in plants in greenhouse, whereas in field experiments, Cd, Ni and Pb concentration was increased in seeds.

Sewage disposal, without doubt, is a major environmental hazard if sludge effluent is incinerated or just deposited in the vicinity of waste water treatment plants. In this order, the effect of desiccated sewage sludge on few soil properties like pH of soil is very much influenced by sewage sludge application. Sewage sludge application to soil makes it more acidic and increases its electrical conductivity. In continuation with this study, sunflower (*Helianthus annuus* L.) plants exposed to sewage sludge in soil showed increased availability of nitrogen and phosphorus to plants. As a result, stem height, dry biomass of root and shoot was enhanced together with an increase in net $CO_2$ assimilation and a decrease in the rate of transpiration and stomatal conductance with an increase in sewage sludge concentration (Elloumi et al. 2016). Sewage sludge application results in a huge enhancement of biomass of willow (*Salix viminalis*) plant coupled with safeguard against oxidative damage and maintain the osmotic balance between the plant root and soil water (if the plant grows in low-grade soil). Catalase activity and proline content were also enhanced in this plant (Wyrwicka and Urbaniak 2018). Recent studies suggested that vermicomposting may be reducing the threat of contamination of heavy metal from sewage sludge (Zuo et al. 2019). It is well known that sewage sludge is a cost-effective and competent soil improvement method although the heavy metal contamination and accumulation is a major concern related to sewage sludge application. These days, sewage sludge alteration into vermicompost via earthworms might be the most successful method to reduce the heavy metal threat, which is very common in sewage sludge application vs direct application method. Vermicompost amendment enhances the quality of soil like decreasing soil bulk density, salinity and pH, increasing soil organic carbon, nitrogen and phosphorus contents in soil. As a result, biomass and yield of maize crop were considerably increased (Zuo et al. 2019). Although vermicompost amendment enhances accumulation of Cd, Cu, Mn, Ni, Pb and Zn in maize plant, particularly in roots. About the differences between sewage sludge application and vermicomposting application (under the situation of maintaining the same carbon input), heavy metals are permitted to accumulate in a more constant binding form in the top layer (approx. 20 cm) of mudflat soil. So, the danger of surface run-off and leaching of heavy metals and their bioavailability to plants is reduced in mudflat soil. So, vermicomposting application can decrease the accumulation of heavy metals in plants if compared with sewage sludge application (Zuo et al. 2019).

## 6.6 Conclusion

To feed the ever-increasing population, global agriculture is required to boost food production. To fulfil this demand, increasing use of chemical fertilizers causes various detrimental effects on human health; sewage amendment is a useful tool as organic manure. With increasing population, sewage sludge is escalating; thus, the significance of its harmless and sustainable discarding is also necessary. Sewage sludge application is the most effective, economic and efficient soil improvement method. Although sewage causes much pollution like soil and water pollution, proper and limited use of sewage water can take care of soil and improve quality. Transformation of sewage sludge compost mainly by vermicomposting via earthworms may be one of the most efficient tools to diminish the threat of heavy metal contamination caused by direct use of sewage sludge. Vermicomposting may be a safe alteration for sewage sludge.

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