Chapter 12
Soil Contamination from Construction Projects

Sirat Sandil and Rabindra Kumar

Abstract Soil plays an essential role in carrying out various ecological functions, acts as a medium for plant growth, and is a base for construction works. Soil contamination is a growing environmental concern worldwide due to the rapid rate of urbanization and industrialization. The problem is pronounced in densely populated countries, where land-use intensity is severe due to construction activities. Procurement of building materials, their manufacture, and processing are environmentally destructive processes, and environmental damage has increased due to an increase in demand for individual living spaces. Further, the construction sector releases a huge amount of hazardous and non-hazardous construction and demolition waste, which negatively impacts the environment through contamination of soil and water. Urban agriculture carried out on contaminated soil leads to an elevated concentration of toxic elements in crops, and consumption of these crops poses a potential health risk to human beings. Construction materials both in existing structures and in new ongoing projects influence the soil on which the construction has been carried out and the soil in its vicinity. In this chapter we elaborate on the different construction and building materials, and how their extraction, manufacture, and usage negatively impacts the soil.

Keywords Construction sector · Construction waste · Demolition waste · Environmental impacts · Soil contamination · Urbanization · Waste disposal

12.1 Introduction

During the last century, the environment has rapidly become contaminated due to uncontrolled industrialization and incessant sprawl of urban areas. The negative impact of human activities on the environment has increased at an alarming rate

S. Sandil (✉)
Cooperative Research Centre of Environmental Sciences, Eötvös Loránd University, Pázmány Péter sétány 1/A, H-1117 Budapest, Hungary

R. Kumar
Faculty of Health Science, University of Pecs, Vörösmarty Mihály Utca 4, 7621 Pecs, Hungary

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especially after the industrial revolution. Environmental contamination and degradation are a serious concern all over the world, especially in countries with a dense population, because they pose major environmental and health issues. An increase in population results in an increase in the needs and wants of the people which produces a degrading effect on the natural resources. Construction activities play an important role in improving the economic status of a society, but they are one of the greatest factors deteriorating the environment. The construction sector globally consumes a major portion of the raw materials and energy which leads to the depletion of natural resources (Singh et al. 2011). Traditional building materials like sand, stone, gravel, timber, cement, and steel are all procured from the natural environment, which results in damage to the environment due to exploitative practices (Pappu et al. 2007). Pollutants arising from construction and demolition activities are myriad and are produced at all stages beginning from the construction materials extraction and manufacturing process and ending with their disposal (Ponnada and Kameswari 2015). Large quantities of wastes are produced by the construction sector in form of construction and demolition waste, industrial by-products from extraction and processing of raw materials, mining and smelting waste, and energy utilization-related wastes. These end-products pose a great challenge for proper disposal due to their high volume and are thus dumped in landfills (Chowdhury et al. 2010). This massive amount of waste poses a significant management problem due to its large volume. Such a huge volume of waste is a problem for the environment, economy, and society (Ginga et al. 2020). The construction sector consumes about 50% of the natural resources and emits about 40% of the global greenhouse gases. The emissions are highest during the construction phase when raw materials are being extracted and processed (Assefa et al. 2007; Hossain and Marsik 2019). Construction and demolition sector and mining and quarrying industry generate the maximum waste as compared to any other sector (Cardoso et al. 2016).

Soil is a natural resource, which provides human beings with raw materials, renewable energy, food, feed, and fiber. It is an essential component of the biosphere because it provides a medium for plant growth, helps in the cycling of nutrients, and maintains the ecosystems and climate (Jie et al. 2002; Harrison and Alloway 2016). It comprises unconsolidated weathered materials derived from the bedrock, decaying organic matter, air, water, and microorganisms (McClintock 2015). Anthropisation or human activities like mining, construction of buildings and roads, and disposal of waste result in deforestation and contamination of soil. Removal of vegetation affects the soil and water quality, increases soil loss through erosion, and rapidly depletes soil fertility by removing nutrient-rich soil. Construction activities destroy the soil at the construction site and contaminate the surrounding soil due to the weight of the structures built on the soil, removal of vegetation, production of wastes and dust, and toxic emissions (Fig. 12.1). Such activities alter the physical, geological, chemical, and biological nature of the soil due to organic and inorganic pollution, and the extent of soil pollution depends on the type of land use (Joimel et al. 2016; Artiola et al. 2019). Interaction between building materials and the environment occurs through the entire life cycle of the construction and has a negative impact (Kobetičová and Černý 2017). Soil removed by excavation, road construction wastes, construction and

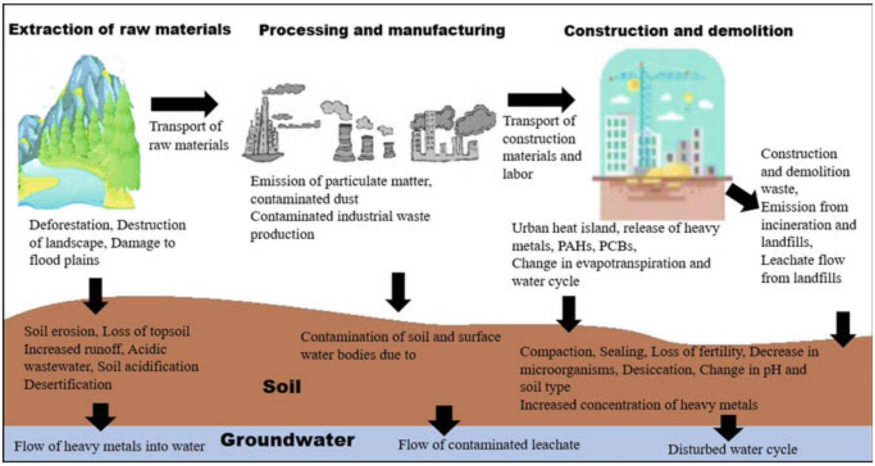

Fig. 12.1 Construction activities related impacts on the soil and groundwater

demolition (C and D) waste, waste rocks, dredge spoils, mine tailings, or mineral waste make up about 97% of the total waste (Cardoso et al. 2016). Soil pollution has a major effect on the sustainable development of the environment and the health of human beings (Yu et al. 2019). To assess the negative impact of construction-related activities on the soil it is essential to consider all stages of the construction process like raw materials, their mining and manufacture, transport, building process, life cycle, demolition, and waste disposal.

12.2 Soil and Its Ecological Importance

Soil is defined as the unconsolidated mineral-rich upper layer of the earth's crust which is an essential part of the ecosystem. Soil develops and serves as a host for various purposes at the interface where there is an interaction between the biosphere, atmosphere, lithosphere, and hydrosphere. Soil is a complex habitat that provides the necessary resources for all living beings and regulates the earth's environment (Singh et al. 2014; Voroney and Heck 2015). Soil is a non-renewable resource, which faces many ecological threats such as organic matter decline, salinization, desertification, and biodiversity loss. Soil pollution still does not generate as much concern as that of air and water pollution and has not received proper attention from citizens and policy makers (Doula and Sarris 2016). Soil is formed from consolidated rock and unconsolidated parent material along with the material deposited by gravity, water, and wind (Olson 2004). Soil formation is a vigorous process depending on five main factors: climate, parent material, topography, time, vegetation, and interaction with living organisms. These factors operate on all soil-forming materials and their relative influence varies with soil type and the geographical location (Harrison and

Strahm 2008). The process of soil formation consists of three stages, overlapping each other: (1) weathering of the parent material; (2) formation of clay and accumulation of organic matter; and (3) translocation of matter and differentiation of horizons. This whole process culminates into a characteristic soil profile, displaying variation of soil properties with depth. Soil forming factors give rise to distinctive soil types depending upon their surrounding environment (Hillel 2008). Examination of a vertical section of soil reveals the occurrence of individual horizontal layers. A well-developed soil profile comprises distinctive layers known as horizons (Brady and Weil 2004). The upper horizon is the A horizon or in popular parlance the topsoil, the zone of major biological activity. In this zone, a largely diverse multitude of microorganisms interacts with plants, animals, and the wastes generated by them. The A horizon is the most fertile part of the soil, rich in organic matter and nutrients. Underlying the A horizon is the B horizon (the subsoil), described as the zone of illuviation (washing in). It is the layer where materials such as migrating clay particles and soluble materials leached from A horizon manage to accumulate. The clay-enriched B horizon contains more clay, but less organic matter and it is thicker than the A horizon. Beneath this layer exists the undifferentiated zone called the C horizon (the parent material). It consists of fragmented and partially weathered rock material, transitioning between the original bedrock below and the soil above (Hillel 2008).

Soil is a dynamic living resource, which needs a minimal environment to carry out its essential functions of conservation, food production, and establishment of a quality environment (Doran and Parkin 1996). Soil produces food, raw materials, and biomass. It plays an important role as a gene pool and habitat and acts as a platform for human functions, landscape, and an archive of heritage. It conserves, filters, and transforms substances, such as nutrients, water, and carbon. It is in fact the largest carbon store in the world (Adriano et al. 1998). Quality of water is directly linked with soils; the soil is a buffering and filtering medium for contaminants. Several physical and chemical characteristics of soil result in clean groundwater for people and animals. Contaminants in soil limit its permeable surface by compaction and sealing, thus affecting its ability to act as a buffering and filtering medium for water. Presence of contaminants also causes extreme changes in soil pH which can drastically affect its retention capacity, triggering the sudden release of contaminants into the groundwater (Doula and Sarris 2016). Soil organic matter (OM) is essential in relation to soil fertility, sustainable agricultural systems, and productivity of crops. The volume of OM in soil depends on the input of organic material, its decomposition rate, the rate at which OM is mineralized, climate, and soil texture. The percentage of OM in clayey soil will be higher than in sandy soil, and in any soil type the OM will be higher for soils with permanent grass cover as compared to soils undergoing continuous arable cropping (Johnston et al. 2009). Soil is essential for construction and building activities. It is directly used to make building materials, such as brick and cement. It is also used to cultivate plants that supply other building materials like timber, wood boards, and insulation fibers. Soils with finer structures are more stable. Clay soils are more stable for construction as compared to sandy soils due to better structure (Joimel et al. 2016).

12.3 Construction Projects and Construction Materials: Extraction, Manufacture, and Transport

The use of raw materials for construction is increasing worldwide because there are lesser people living together in a household and there is a demand for new individual dwellings. Coupled together with the increase in houses, the population requires a certain standard of living which can be enabled by the construction of efficient and extensive roads, airports, and harbors, increased construction of schools, hospitals, shopping malls, office spaces, playgrounds, parks, underground tunnels, etc. (Douglas and Lawson 2003). This leads to an increased spate of building construction. The increase in construction-related activities has a dual impact on the environment. The fast-paced removal of raw materials from the natural environment changes the geomorphology of the natural landscape. Alongside the application of these raw materials and their processed by-products and end-products like concrete in the urban environment changes the urban morphology (Douglas and Lawson 2003). Due to the large number of construction projects happening in the world, construction-related activities have a negative impact on the environment. The operation and maintenance of a completed building produces a significant impact on the surrounding environment. Construction is not an environment-friendly process (Babak 2017). A large amount of energy and raw materials are consumed during the extraction of raw materials, processing and manufacturing, transportation, and construction. Demolition and disposal of wastes is also an energy intensive process (Nautiyal et al. 2015). C and D waste arise from construction activities, partial or complete demolition of constructed spaces like buildings or infrastructures, wastes produced during renovation and maintenance, constructing and maintaining roads, and debris arising during any disaster (Kumbhar et al. 2013; Silva et al. 2017).

The building construction sector is a major consumer of energy and raw materials and has a huge impact on the environment. It emits about 33% of the global carbon dioxide and thus is the second-largest emitter (Zhang et al. 2013). Construction of a building or any other structure requires various raw materials like masonry, sand, timber, and materials prepared through numerous manufacturing and processing techniques. Construction in early times was an ecofriendly process involving biodegradable materials like mud, rocks, and wood, but now it heavily utilizes man-made materials like concrete, bricks, plastics, and glass, which cannot be biodegraded easily (Nautiyal et al. 2015).

Concrete is used in all construction works and is prepared using aggregate, sand, and cement. To increase the strength of concrete, steel bars and fiberglass are used. Another type of concrete uses gypsum plaster with sand and cement. Bricks are important building materials. They are of two types, mud bricks which are air-dried, and fired bricks, which have been treated with fire to increase their durability. Masonry like rocks or stones are highly durable materials used for constructing walls and foundations. They are long-lasting, strong, and heavy and were used for construction in the past (Nautiyal et al. 2015). Cement is a vital building material that is used widely. Cement production factories are a chief source of pollution due to the emission of dust which contains toxic substances like heavy metals (HMs). Dust pollution affects the soil, vegetation, and air in the vicinity of the manufacturing plant. This dust settles on the surrounding soil and is spread further by wind and rain, contaminating the soil. HMs in soil are toxic for the plants and microbes growing in the soil, and the extent of toxicity depends on the metal concentrations. Cement dust settling on soil can negatively impact the soil microorganisms (Isikli et al. 2003; El-Sherbiny et al. 2019; Semhi et al. 2010). Cement dust comprises calcite, dolomite, quartz, and clay minerals, and HMs. HMs in dust were highest near the factory and decreased with distance (Semhi et al. 2010). The dust also contained a significant amount of chromium (Cr) and cadmium (Cd) because of its presence in the machinery (Isikli et al. 2003). Timber is a recyclable and compostable material. It is used for building doors, windows, frames, and furniture. In some places, entire homes are built with timber. They are also used for flooring in cold climates. Timber production causes large-scale deforestation and soil erosion.

Asphalt is used in the construction of roads, bridges, flooring materials, parking lots, and roofing materials. Tiles and ceramics are used as flooring, ceiling, and roofing materials. They are also used on walls. They are lightweight, have a good appearance, are scratch proof, and moisture resistant. They are manufactured using glass and metals (Nautiyal et al. 2015). Marble is highly used for flooring, and its cutting, polishing, and processing produces about 6 million tons of waste only in India. This marble dust is disposed of in riverbeds and reduces soil porosity and permeability, resulting in water logging. The dust remains suspended in the air during the dry season around the manufacturing and disposal site. It increases the soil alkalinity and settles on vegetation affecting their growth (Pappu et al. 2007). Asbestos is a mineral resistant to heat and degradation, used in products like asbestos cement, adhesives, automotive brake, insulation, roofing, and flooring material. Despite being banned in over 50 countries, asbestos-containing products remain intact due to past usage and asbestos production remains steady in other countries like China, Russia, and Brazil. Asbestos is present in dust due to anthropogenic activities which disturb rocks and soil like construction of buildings, roads, and mining (Noonan 2017). Glass is made from sand and silicates, and its manufacture consumes a high amount of energy. It is used in windows and doors, to cover walls, and as partition material. Quartz or silica is a common material found in soil, sand, concrete, granite, masonry, and landscaping materials (Li et al. 2019). Gypsum is used in the construction of wallboards and interiors. Fiber is used in insulation and ceiling system materials. Plastic and polyvinyl chlorides (PVC) are manufactured through polymerization. They are extremely lightweight and have high plasticity. They are used as covering of electrical wires, for carrying water, and in sanitary applications (Nautiyal et al. 2015).

A lot of construction material especially metals are obtained through mining, which causes soil and land pollution. Metals like iron (Fe), aluminum (Al), copper (Cu), lead (Pb), cadmium (Cd), nickel (Ni), zinc (Zn), mercury (Hg), and arsenic (As) are used in the manufacture of a lot of industrial and construction products. HMs like Cd, Cu, Pb, Ni, Zn, Hg, and As are the most hazardous soil pollutants. They are persistent in the soil environment and cannot be degraded. Metals adsorbed on soil can find their way into surface water bodies or groundwater. These further find their way into the food chain through crops grown on contaminated soils or through contaminated drinking water resources (Mulligan and Galvez-Cloutier 2003). The use of metals in the construction sector has increased over the years due to extensive construction activities being carried out. Metals are used to provide structural strength to constructed spaces. They are also used in electrical and sanitary fittings, household appliances. Steel is extensively used in the construction sector due to its durability, strength, and flexibility. Tin (Sn) and aluminum (Al) alloys are also used because they are lightweight and resistant to corrosion (Nautiyal et al. 2015). Natural Cd is found in shale deposits. Sources of Cd in the construction sector are steel plating, Ni–Cd batteries, pigments stabilization, Cd alloys, polyvinyl chloride plastic (PVC), rubber, solder, electroplating, motor oil, and dust produced in cement manufacturing. It could enter the soil through mining waste, disposal of C and D waste on landfills, landfill leachate, leakage from hazardous waste sites, and household waste. Cu is naturally found in sandstones. In the construction sector, it is used in building materials and has industrial applications due to its lightweight, and resistance to corrosion. It is used in roofs, domes, cladding of walls. Sources of Pb are paints, Pb–Zn smelters, batteries, glass, and piping. Sources of Zn are alloys of bronze and brass, rubber, products of galvanization, metal coatings, glass, smelting, and refining of ores, mechanical abrasion of tires, and cement industry (Mulligan and Galvez-Cloutier 2003; Al-Khashman and Shawabkeh 2006). Cr is released by ceramic materials and carbonated samples. Al production requires high energy requirements which put a huge burden on the environment. Alongside, many other pollutants like PAHs, PFCs, CO_2, and SO_2 are also released as by-products of the production process (Diotti et al. 2020).

Despite its economic benefits, mining produces large amounts of useless geologic materials containing a high amounts of toxic metals which are disposed of on-site. Mining activities degrade the soil and water resources and destroy the visual environment. Mining produces two types of waste: (i) mine tailings which are crushed mineral rock from which the desired metal has been extracted, and (ii) mine spoils which are waste rock materials not containing the desired metal. Both mine tailing and spoils containing toxic materials are disposed of in depression or open pits, making the site unstable and susceptible to weathering. Mining operations also give rise to acidic wastewaters when the extraction of metal requires acids, furthering pollution of soil (Artiola et al. 2019; Nguyen et al. 2021). Nguyen et al. (2021) studied soils at five sites near a mining area in Vietnam. They reported that all soils in the vicinity of the mining area had a higher concentration of HMs, and Zn, Cu, and Pb were the dominant HMs at all sites. The type of HM in soil varied with the mining site. Higher Pb was present at the site of clay and rock mining, while Cd and Zn were dominant at the site of clay and bauxite mining.

Pollutants produced in the metallurgical industry cause soil pollution when the waste product (sludge, slag, linings) containing heavy metals are dumped in the landfills. Processing, manufacturing, storage, and delivery of raw materials and end products, and disposal of wastes involves the release of contaminants. These contaminants can spread to wider areas attached to dust and particulate matter, and the area they will spread to depend upon the wind and precipitation factors. Pollutants produced in the metallurgical industry impact the soil, water, and air. Common pollutants are HMs, dust, H_2SO_4, HCl, toxic gases, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs). The fumes and dust produced during the process also impact soil when they get deposited on the surrounding soil (Sofilić et al. 2013). The rate of pollution will depend on the material being extracted, type of pollutant produced, place of extraction, and the technical procedure applied (Sofilić et al. 2013).

12.3.1 Transportation

Environmental impacts related to transport are manifold: they arise due to vehicle use; production, maintenance, and disposal of the vehicle; and the production of building materials, construction, maintenance, and demolition of the roads, railway tracks, air field, bus, and railway station, and airport. The effect on the environment occurs not only in the vicinity of the road or airport but also at the site from where the raw materials have been procured (Douglas and Lawson 2003). Construction of transport-related infrastructure has additional requirements like the need for office buildings, gas stations, diesel depot, garage, and blocking posts (Babak 2017). Transportation of raw materials and other industrial products to the construction site requires a well-developed road network. All types of construction activities require a large amount of labor, which need to be transported to and from the construction site in vehicles, thus traffic in urban areas contributes significantly to HM pollution (Li et al. 2013). Transport of materials and labor to the construction site has an impact on energy consumption and the environment. Vehicles use energy and emit gases and particulate matter. The fuel consumption will depend on the distance of the construction site from the raw materials procurement site (Cole 2000). Vehicles emit pollutants through the leaking of oil and coolants, corrosion, and wear and tear of parts like tires, brakes, and engines. They release PAHs and Pb by combustion, Cu from the corrosion of brakes and radiators, and Zn from tire dust. The pollutants are spread by wind or water runoff from the road surface which collects the contaminants and transports them to the soil at the sides (Van Bohemen and Van De Laak 2003). Construction of roads has several environmental impacts like deforestation, loss of habitat and habitat fragmentation into small patches, erosion on the road surface, increased sediment runoff during precipitation, pollution of nearby water resources, and slope failure in certain cases (Caliskan 2013). During the construction of roads in a mountainous region in Turkey, Caliskan (2013) reported the destruction of 33–44% of trees by bulldozers.

12.3.2 Energy Requirements

Construction projects and related transportation requires a lot of energy supplied by oil, gas, and coal. The extraction of oil and coal burning for electricity also pollutes the soil. Crude oil drilling uses fluids of high density like sodium chloride, which are disposed of in the oil wells when they are spent. This produces highly saline land and water. Extraction of gas through hydraulic fracturing produces geologic water and sludge with high radioactivity. Combustion of coal for electricity produces fly ash, which is disposed of in ponds or landfills or used as filling material in construction. Depending on the source of the coal, fly ash contains different level of HMs, which can cause soil and groundwater pollution (Artiola et al. 2019). Coal-fired power plants produce coal slag containing HMs like Cd, Cr, Cu, Zn, Au, Hg, and Pb, which leach into the topsoil and contaminate it. Runoff water and erosion help the HMs in infiltrating the soil layers. Liu et al. (2017) studied HM contamination from a coal-fired power plant in Mongolia and reported the HMs concentration to be twice the acceptable concentration. The HMs contamination was also found to increase in the area with increased construction activity, probably due to change in soil pH or reduced absorption by the vegetation. They analyzed the ecological risk posed by the HM contamination and found it to be in the following order: Hg > Cd > As > Ni > b>Cu > Cr > Zn, with the probability of further increase if the construction activities continued unabated. Hg and Cd were high-risk elements while Ni, Pb, Cr, and Cu were medium risk and Zn was a low-risk element.

12.4 Wastes Generated During Construction and Demolition and Their Disposal

The construction and demolition (C and D) industry produces a huge amount of waste every year during the process of construction, demolition, renovation, and maintenance of buildings and infrastructure. Table 12.1 lists the amount of C and D waste produced in some countries. Approximately 10 billion tons of C and D waste is produced worldwide every year which due to its increasing volume poses grave

Table 12.1 Construction and demolition waste produced in different countries

Country	Construction and demolition waste produced per year (tons)	References
India	10–12 million	Ponnada and Kameswari (2015)
Canada	9 million	Yeheyis et al. (2013)
China	2.3 billion	Chen et al. (2020)
USA	700 million	
European Union	857.1 million	Rodríguez-Robles et al. (2015)

environmental impacts (Chen et al. 2020; Ginga et al. 2020). C and D wastes represent one of the biggest waste streams by weight and volume (Diotti et al. 2020). C and D wastes arise from new constructions in process, existing building structures, total or partial demolition of structures, maintenance activities, and road construction. They form a major portion of the municipal solid waste (MSW), generally comprising 20–30% and sometimes up to 50% of the MSW. The majority of the C and D waste is inert, without putrescible materials, since it mainly comprises bricks, concrete, sand, gravel, asphalt, masonry, gypsum, asbestos, and wood. It also contains plastics, metals, insulation materials, glass, cardboard, and paper (Qiang et al. 2015; Yeheyis et al. 2013; Silva et al. 2017). Wastes are generated in the construction phase of a building due to ordering of excessive material, mixing undue amount of materials like concrete or mortar which is ultimately not used, material which is not properly packed and thus spoilt like sand lime bricks, breakage of material during transportation, use of inadequate equipment, improper cutting for stone slabs or tiles which would result in them being wasted (Bossink and Brouwers 1996).

Waste soil during construction originates from the clearance of the building site, during excavation for building the base of buildings or roads, or sanitation works. The waste materials in soil arise from renovation and demolition work and the rubble remains in the upper layers of the soil. Urban soils contain transported soil, remnants of building material like brick, concrete, or paint, organic materials, ash, slag, and any waste released during building construction (Ottesen et al. 2008). Dust released during construction and demolition activities affects the environment and the health of the people living in the vicinity. All suspended and deposited particulate matter of up to 75 μm in size is called dust. Dust arises from silica and asbestos mining, cement manufacturing, marble, and granite processing, from bare soil produced during construction (Li et al. 2019). The production of concrete involves the release of pollutants like heavy metals, organic pollutants, CO, CO_2, SO, NO, and wastewater. Concrete waste is generated by breaking down of foundations, parking areas, driveways, buildings, sidewalks (Asif et al. 2007). Treated wood waste is generated by plywood that has been pressure/creosote-treated or laminated. Untreated wood waste arises from scraps, tops and stumps, and framing material. Timber in demolition waste can be used for the production of wood chips. The waste from the steel industry contains a high amount of iron and iron-containing alloys. This iron finds its way into the groundwater over time (Jhamnani and Singh 2009). The presence of gypsum in wastes releases a high concentration of sulphate (Diotti et al. 2020). Heavy metals are produced through various anthropogenic activities like mining and metallurgy, from constructed roads and residential complexes. Cd is produced in metal production, waste incineration, fossil fuel combustion, and cement manufacturing. Cr is released by metal processing and production industries, and cement manufacturing due to its presence in the rotary lining. Cu is released by wood and piping, while Ni arises from metal processing and electric and electronic waste. Pb arises from paints, old buildings, and metal processing, while Zn is released by metal processing, cement manufacturing, and vehicular emissions (Kasassi et al. 2008).

12.5 Disposal of C and D Wastes

It is difficult to recycle C and D waste at the end of the cycle because of their high chemical contamination level and heterogeneity. It is thus essential to prevent the generation of C and D wastes in the first place and then recycle whatever is produced (Bossink and Brouwers 1996). The disposal of C and D wastes involves an elaborate process of removal of reusable materials. C and D wastes are crushed, metals that can be reused are separated and undesired fractions are removed. C and D waste can be primarily reused as recycled aggregates instead of being disposed of in landfills. After screening, materials defined as recycled aggregates (RAs) are generated. Their composition varies with the waste composition. The RAs are mainly used in the construction of roads, pavement, and drainage, in place of fresh materials. Recycled aggregates are of several types like recycled concrete aggregate, recycled masonry aggregate, mixed recycled aggregate, reclaimed asphalt, and construction and demolition recycled aggregate, depending upon their principal component (Cardoso et al. 2016).

C and D waste are generally disposed of in landfills, and only a small amount is currently recycled. When disposed of in landfills they occupy large areas. Such wastes are heavy and bulky, and thus unsuitable for incineration or composting (Ponnada and Kameswari 2015). Landfills are the cheapest and simplest methods for waste disposal and a major proportion of wastes are dumped in landfills. Landfills are generally situated in existing holes like mines, to reduce costs involved in excavations. When landfill lining with minimum thickness is placed in such areas then there is very little barrier existing between the soil or groundwater and the wastes. Any crack in the lining leads to leakage of the leachate which contaminates the soil and water. Waste degradation in landfills takes a very long time, spanning over 20–30 years and more. During this time the lining of the landfill is susceptible to leakage (Allen 2001). Up to 80% of the demolition waste can be recycled on-site. In contrast, when they are dumped on landfills they are altered physically, mixed with other wastes, and become further contaminated, preventing any reuse or recycling (Cole 2000).

12.6 Effect of Construction Activities on Landscape and Soil Environment

All over the world, the number of people living in urban areas is very high. About 54% of the world's population lived in urban areas in 2014, and this percentage was up to 73% in regions like Europe (Yang and Zhang 2015). The rapid pace of urbanization has augmented the rate of resource consumption and the corresponding environmental degradation. The greatest threat of urbanization is on the soil in the urban areas (Xiang et al. 2020). Cities cover 2% of the land and produce up to 80% of the urban and industrial wastes which affects the urban ecosystem. Urban soils receive a high amount of these wastes which undermines their role in providing ecosystem services, and at this rate could convert the soil from a sink to a source of contaminants (Yang and Zhang 2015). Certain effects of construction activities on the environment are given in Table 12.2.

12.6.1 Impact of Construction Activities on the Landscape

Natural landscape changes on the earth's surface are brought about by the activity of water, ice, or wind. Construction activities can transform the landscape at a faster rate as compared to these natural agents and are thus the most efficient agents changing

Table 12.2 Negative impacts of construction activities on the environment

Stages of construction activity	Effect on the environment	References
Production, manufacture, and transport of building material	• Destruction of natural landscape and soil during extraction of raw materials • Formation of highly contaminated and acidic wastewater during extraction or mining process • Emission of toxic gases during procurement, manufacturing, and transport of raw materials • Emission of dust and particulate matter • Heat pollution • Noise pollution • Destruction of topsoil, which impacts the soil composition and its associated organisms • Increased soil erosion, acidification, and desertification • Increase in runoff and higher chances of flood • Impact on plant growth, habitat, and agriculture	Caliskan (2013) Babak (2017) Burghardt (1994) Allen (2001) Dziri and Hosni (2012) Gangolells et al. (2009) El-Sherbiny et al. (2019)
During construction	• Air pollution due to emission of gases • Emission of particulate matter • Industrial and municipal solid waste formation • Contamination and destruction of soil at the construction site and in the surrounding areas • Destruction of forested areas, water bodies, wetlands	Dziri and Hosni (2012)

(continued)

Table 12.2 (continued)

Stages of construction activity	Effect on the environment	References
During the lifetime of the constructed space, after demolition, and during disposal	• Disturbance of the water cycle due to limited percolation of water in areas covered by buildings or concrete • Change in the temperature of the area due to change in albedo, formation of urban heat island • Emission of greenhouse gases during combustion • C and D wastes comprise a huge fraction of the municipal solid waste • Leachate runoff from landfills, which contaminates soil and groundwater	Allen (2001) Jhamnani and Singh (2009) El-Fadel et al. (1997)

the geology and geomorphology (Douglas and Lawson 2003). Construction activities on steep slopes or on captured flood plains are responsible for economic and livelihood loss (Ferreira et al. 2018). The type and location of urban construction and surrounding land use greatly affect pollutant deposition. Isolated houses with gardens and urban drainage contribute higher pollutant load as compared to residential complexes due to greater garden and road surface area (Ferreira et al. 2018). The urban constructed areas comprise of different land uses like residential buildings, industries, businesses, traffic, parks, and gardens, which have different human activity and thereby a varied impact on the soil, resulting in a mosaic of soil types with dissimilar qualities. Land use and vegetation cover can be an indicator of the degree of pollution and disturbance in an area (Li et al. 2013). In a study on HMs contamination of urban soil in an old industrial city in China, Li et al. (2013), observed that pollution levels varied with the land use type. Industrial lands were the most contaminated followed by construction lands, and then roads. Soil contamination was higher in the vicinity of industrial areas, but pollution could spread to large areas due to wind and precipitation (Fazeli et al. 2019).

Land degradation is the reduced ability of the land to serve in functions like agriculture, construction, transport, etc. (Jie et al. 2002). Deforestation is the removal of large tracts of forests for agriculture, construction, building roads, and mining purposes (Jie et al. 2002). Forested areas are cleared to make space for mining activities, or roads, or to harvest timber needed for construction or as a fuel source. Removal of forest decreases soil stability and makes soil vulnerable to erosion by wind or water. During precipitation, an increased rate of runoff can erode the soil and carry large amounts of sediment downstream. Loss of vegetation leads to soil degradation, desertification, loss of biodiversity due to habitat fragmentation, diminished air quality, and an increase in temperature (Artiola et al. 2019).

12.6.2 Impact of Construction on Soil Environment

Soil composition depends on the initial parent material of the soil, which is acted upon by factors like climate, biota, and topography. Soil is a product of chemical and physical leaching, oxidation, and dissolution of the parent material (Olson 2004). Soil quality is defined by the ability of soil to carry out its essential functions and provide ecosystem services. It is determined by the fertility and the contamination status of the soil (Joimel et al. 2016). Soil is an important natural resource because it acts as a geochemical reservoir for contaminants like heavy metals arising from construction and industrial activities (El-Sherbiny et al. 2019). Any change in the soil quality is dependent on the type of anthropic activities carried out on the soil. Man uses the land to obtain resources and products from it. This usage of the soil environment could be through agriculture, forestry, urbanization, or industrialization, each of which brings about a modification in the natural state of the soil and landscape. The rate of change related to these activities will depend on the duration and intensity of the anthropogenic activity (Joimel et al. 2016). Soil contamination is the accumulation of toxic substances like heavy metals and organic pollutants in the soil (Sharma 2017), at concentrations which would impair the normal functioning of the soil, disrupt vegetation and the biological cycling of the nutrients (Scullion 2006). Soil contamination could also affect the groundwater quality through the percolation of contaminated leachate and pose a danger to aquatic ecosystems, and human health (Scullion 2006).

Soil degradation refers to the loss of the soil's ability to produce plants, which results in food insecurity. Soil degradation occurs through the process of erosion (loss of soil), compaction (decrease in soil space due to mechanical stress), depletion (loss of soil organic matter, fertility, and biological material), and accretion (addition of pollutants to soil, acidification, or alkalinization) (Jie et al. 2002). Soil degradation is a natural process like soil formation which takes place over many years, due to factors like erosion, desiccation, salinization, and compaction of the soil. All these factors are very slow and there is enough time for the regeneration of soil. But a new cause of soil degradation, urbanization is rampant now, which is very fast-paced and does not allow recovery time to the soil. Rapid urbanization is a major cause of soil degradation because of the high population of people living in urban areas (Jie et al. 2002). Anthropogenic activities alter the distribution pattern of materials in the ecosystem. Urban land use can diminish the soil capacity of storing toxic substances like heavy metals and PAHs. It can also impair the ability of the soil to provide ecosystem services. This affects the availability of water, food, and energy to the urban population, and increases their vulnerability to natural hazards (Burghardt 1994).

12.6.3 Formation of Urban Soil

Soil pollution in urban areas is very complex and can pose a serious health risk to human beings. Due to more pollution sources in the urban environment, a large number of pollutants find their way into the soil (Yu et al. 2019). In urban areas, anthropogenic activity is a prominent factor controlling soil quality. Change in land use in urban areas occurs through the construction of residential buildings, schools, playgrounds, etc. The construction of these complexes involves the sealing of the soil surface and sub-surface, construction of underground drainage systems, and laying of pipes for water supply, which gives rise to many watersheds. These activities can alter the percolation of water into the soil and evapo-transpiration, and modify the ability of soil to accumulate toxic substances (Burghardt 1994). Urban soils are comparatively younger due to the mixing of soil layers, and due to the addition of new materials during construction. Modification of urban soil can occur through soil sealing, compaction, excavation and relocation of soil, mixing and filling with other materials (aggregates, ash, building rubble, slag) during construction, contamination (due to construction work, waste disposal, de-icing salts, leakage), and desiccation (lowering of groundwater levels due to reduced water inflow) (Niemelä and Sauerwein 2013). They are excavated, transported, and mixed with other soils on site, causing variation in soil from one place to another, depending on the land use (Li et al. 2013; Meuser 2010). Urban soils are a mixture of anthropic (altered by human influence) soil bodies and unaltered natural soil bodies, together classified as technosols. Soil type is not predetermined, it develops over time depending on the parent material and geogenic and anthropogenic processes. Anthropogenic activities like building construction and demolition, roads, extraction or addition of man-made aggregates (concrete, mortar, asphalt), excavation, and disposal of soil, all impact soil formation and composition (McClintock 2015).

12.7 Effect of Construction on Soil pH, Texture, and Nutrients

Soil pH and texture are dependent on the parent material, land use, and type of anthropogenic activity, and its intensity (Romzaykina et al. 2020). Soils affected by anthropogenic activities display increased pH levels. Kosheleva et al. (2018) reported an increase in pH to 7.5–8.6 in urban areas, caused by the presence of dust, ash, and the dissolution of technogenic materials. Alkalinization is caused by dust deposits from the manufacturing of cement or concrete, processing of marble, and gravel. Disposal of waste and atmospheric deposition from traffic or industries also increases the pH (Joimel et al. 2016). Marble and cement production releases a lot of dust which settles on the surrounding soil and the disposal site, turning the soil alkaline and reduces soil pore size and permeability (Pappu et al. 2007). Urban soils contain a lot of technogenic materials (debris of bricks, rubble, ash, slags, plastics, metals, etc.) other than their original weathered parent material. The presence of sand, gravel, and other demolition wastes in the soil makes the soil more sandy and reduces the fine earth content. Biasioli et al. (2006) reported high pH (up to 8) and high sand content (439–889 g/kg) in urban soils. The high sand content was due to the presence of extraneous coarse materials. Demolition waste like ash, slag, and rubble also change the shape of soil. Soils had a higher fraction of coarse materials and little effect of the parent material. The change in soil texture and shape reduces the water storage capacity of soils and increases the concentration of air-borne contaminants, further enhancing the flow of contaminants into the groundwater. The particles from demolition materials are sharp edged and increase the shear resistance of soil. Their presence hinders the growth of plant roots and occurrence of earthworms. They also prevent the movement of organic substances in the soil, thus limiting the organic matter (OM) to the surface layers. Soils with high OM can bind HMs, preventing their movement into the groundwater. Urban soils also contain a higher amount of black carbon probably contributed by coal fly ash (Burghardt 1994; Yang and Zhang 2015).

Urban activities alter the nutrient content of the soil, especially increasing the P concentration due to added depositions (Joimel et al. 2016). P enters the urban soil through organic manure or sewage sludge and is harvested when plants are cultivated in the soil. But in the case of urban soils, P is not recycled and remains at a very high concentration in the urban environment. This increases the chances of water pollution. Urban environments also alter the carbon and nitrogen content, and soil temperature (Romzaykina et al. 2020).

12.7.1 Physical Degradation of Soil Due to Constructed Spaces

Construction of buildings or roads, airports, or railway tracks causes the sealing and compaction of soil due to the use of heavy machinery and due to the increased weight on soil. Intentional compaction is carried out for building foundations of houses, paving roads, and using heavy machinery for sloping banks on roads or hillsides. Unintentional compaction occurs due to the high traffic burden on soil (Yang and Zhang 2015). Sealing and compaction of soil causes high horizontal and vertical variability in the soil profile depending on the type of anthropogenic influence (Biasioli et al. 2006). Soil compaction causes the physical deterioration of the soil by destroying soil structure, air porosity, reducing the storage capacity of soils, which reduces the movement of water through the soil. It also affects the biological activity in the soil and decreases biomass productivity. Compacted soil restricts the movement of water and air and restricts the growth of roots. Such soils are prone to erosion due to the presence of scarce vegetation (Jie et al. 2002).

Constructed spaces utilize extensive amounts of impermeable substances like concrete, asphalt, and tiles. These materials seal the soil and limit its permeability.

Sealing is a permanent process that impacts the soil properties, limits percolation of water and groundwater recharge, inhibits carbon sequestration, disrupts biogeochemical cycling of nutrients, and causes biodiversity loss. It also results in the formation of urban heat islands because sealed areas absorb increased radiation as compared to vegetation (Niemelä and Sauerwein 2013). Compaction and sealing of soil results in decreased water infiltration and reduced groundwater recharge, increased runoff and increased urban floods, higher pollutant load in surface water bodies due to runoff, formation of urban heat island, increased soil temperature and decreased microbial activity, and weakened plant growth (Yang and Zhang 2015).

Soil erosion is a prominent environmental concern worldwide. Soil erosion depletes the fertile layer of topsoil, degrades the land, and increases siltation in low-lying bodies of water. Sediment loss from construction activities is 95% more than that of forested land. In constructed spaces, soil erosion occurs on bare soils deprived of vegetation, on edges of the road, and on railway tracks. This happens because the soil profile is disturbed, and soil is prone to erosion due to rain or runoff water. Gully erosion in urban areas occurs along construction sites, areas of road construction, and urban drainage (Ferreira et al. 2018).

12.7.2 Impact of Construction Activities on Water in the Urban Environment

Constructed spaces modify the water cycle by altering the soil properties. Soils in urban areas are compacted, which reduces their pore space and water holding capacities. Urban soil surfaces are sealed with concrete or asphalt, and vegetation-free, which hinder water percolation into the soil. This results in an increased amount of run-off. The run-off is collected through artificial drainage channels and transferred to streams or sewers. Reduction in water infiltration leads to decreased groundwater recharge and increased surface runoff. Surface runoff in small catchment areas can lead to flash floods during high-intensity rainfalls. Sealing of the soil surface also reduces the evapo-transpiration rates (Yang and Zhang 2015). Pollutants from the urban soil environment like HMs, PCBs, and PAHs, can make their way to water bodies along with storm water runoff from these systems. Pollutants in water are also derived from landfill leachate, sewage systems, drainage of water from urban gardens, soil erosion, and atmospheric deposition. Urban runoff is a major non-point source of pollution due to its high level of contamination with HMs, PAHs, and P. Runoff water contains a high concentration of HMs collected from rooftops, roads, and paving materials. Road runoffs have significant HMs contribution from vehicular emissions. These pollutants can deteriorate the quality of surface and groundwater thereby impacting drinking water and irrigation water sources. Pollutants and sediment from urban areas also affect the aquatic ecosystems. Sediments eroded by the storm water runoffs in urban areas are 60 times higher than sediment runoff from vegetation-covered surfaces. They enhance turbidity, reduce light penetration, inhibit photosynthesis, decrease dissolved oxygen, and cause eutrophication (Ferreira et al. 2018). Impervious urban surfaces enhance the presence of contaminants like HMs, PAHs, and PCBs in the storm water runoff. These pollutants present in the urban soil could be remobilized due to erosion caused by precipitation. Kartun et al. 2008 studied runoff sediments from storm water traps in Norway. The concentration of Pb, Zn, and Cd in the sediments was 9–675, 51.3–4670, and 0.02–11.1 mg/kg respectively. The PCBs between <0.0004 and 0.704 mg/kg, and the PAHs concentration range was <0.2–80 mg/kg. They reported the origin of runoff sediments to be weathering of buildings, construction and demolition activities, and traffic. A high concentration of contaminants in the urban soil was dispersed into sediments through stormwater runoff from the impervious surfaces.

12.7.3 Impact of the Urban Environment on Soil Microorganisms

Urban sealing decreases soil microbial activity, and the influence on soil microbes depends on the land use type. Soil compaction and trampling may destroy the microbial communities existing in the upper 10 cm layer rich in organic matter. The presence of microbes in the soil will further depend on the N and P content of the soil, as they affect enzyme synthesis and processing of organic matter. Microbial activity is an important indicator of soil contamination levels. Contaminated soils have a diminished microbial mass (Yang and Zhang 2015; Havugimana et al. 2017).

12.7.4 Heavy Metals and Organic Pollutants in Urban Soils

Urban soils are the most important sinks of chemical emissions (Ferreira et al. 2018) and serve as indicators of human exposure to contaminants in the soil environment (Li et al. 2013). Soil contamination in constructed environments occurs due to emissions from residential buildings, factories, transportation, fossil fuels, and disposal of C and D waste (Biasioli et al. 2006). End-products from the construction and demolition sector also contain trace amounts of different contaminants which could contaminate the underlying and surrounding soil and groundwater (Chowdhury et al. 2010). Early soil pollution was mostly due to inorganic pollutants, but there has been an increase in pollution with organic pollutants (polycyclic aromatic hydrocarbons) as well caused by fuel hydrocarbons (Scullion 2006). Pollutants in urban soils are inorganic (heavy metals (HMs) or potentially toxic elements (PTEs)), organic (polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and phthalate esters), chlor-organic compounds, and radionuclides (Biasioli et al. 2006).

Heavy metal pollution of the soil is a widespread environmental hazard that damages the soil quality, deteriorates water quality, decreases food production, and leads to the production of unhealthy food crops containing a high concentration of HMs. Heavy metal pollution has now become a regional, compound, and non-point source of pollution (Xiang et al. 2020). Heavy metals in urban areas arise from constructed environments, industrial activities, traffic emission, and atmospheric depositions. Soils close to roads, cement factories, are enriched with HMs. HMs are non-biodegradable and thus persistent in soils for several years even if the source of pollution is removed, and difficult to remediate. They are highly toxic even at low concentrations and have a long residence time in soil. They affect plant growth and soil microbes, food web functions, and disrupt biogeochemical cycles (Kasassi et al. 2008; Li et al. 2013; Liu et al. 2017; Nguyen et al. 2021). HMs in urban environments reach human beings through food cultivated in urban polluted soils, through ingestion of soil, through inhalation of dust-laden with HMs, and dermal contact when working in contaminated soils. Factors affecting HMs mobility are pH, organic matter content, and soil texture. HMs display complex spatial distribution in urban soils and the distribution is affected by soil compaction and zoning (Romzaykina et al. 2020).

Heavy metals concentration in urban areas is always greater than in rural areas due to general and diffuse contamination of soils (Biasioli et al. 2006). In Torino, Biasioli et al. (2006) observed high concentrations of Ni (209 mg/kg), Cr (191 mg/kg), Pb (149 mg/kg), and Zn (183 mg/kg) in the urban soils. Pb, Cu, and Zn were associated with traffic sources, Pb with leaded fuel, Cu from brakes, and Zn from tires. Other sources were probably piping, cables, paints, and incinerators. They concluded that large cities strongly influence soil properties and concentrate HM pollutants in the urban soil. Lead, a persistent HM arises from paint, gasoline, waste incineration, and industrial sources. Pavilonis et al. (2020) reported the presence of Pb in soil despite the ban on Pb in fuel and the absence of smelters. They found old houses painted with Pb-based paints to be the most important source of Pb in soil. An increase in population in the area, and renovation and demolition of old buildings caused the release of Pb-containing dust, which settled on the surrounding soil. A positive correlation has been observed between increased Pb concentration in soil and areas with older houses, which also caused an increase in the blood Pb levels of children.

Vegetation in urban areas acts as a surface for the deposition and immobilization of dust particles. Type of land use significantly affects the HMs accumulation in the urban soil (Xie et al. 2019). This was observed by Xia et al. (2011) in Beijing. They analyzed the concentration of Cd, Cr, Cu, Ni, and Pb in soil samples from gardens, residences, business areas, roadside, and schools. All soil had a higher concentration of Cd, Cu, Pb, and Zn due to anthropogenic effects. Among the land uses, the classical garden had the highest HMs concentration due to historical contamination with wood preservatives, pigments, and brassware. The roadside soil had the second-highest concentration of Cd signifying its origin from traffic sources. HMs concentration was higher in lands used for a longer duration, and in lands nearer to the city. Xie et al. 2019 investigated 115 soils from residential areas in Beijing and observed Cu, Cd, Pb, and Zn to be the most common contaminants in urban residential areas. The HMs concentration was significantly correlated with the age of the buildings, population, and distance to the city center, while building height and green cover did not play a significant role.

Building orientation also affects the deposition of contaminants. High-rise buildings transform the direction of wind creating wind shades in closed areas and canyon effects on large open streets. In closed areas decrease in wind speed causes the deposition of dust-containing pollutants, but in open areas, the dust is blown away. Urban soils in a residential area in Moscow were found to accumulate higher HMs concentration as compared to control soils. The soils contained elevated concentrations of Cd (1.8 mg/kg), Zn (190 mg/kg), Cr (98 mg/kg), Pb (50 mg/kg), and Cu (61 mg/kg). The building orientation affected soil contamination in two ways: (i) they acted as protective screens and disrupted the wind pathway, preventing the deposition of contaminants laden dust in the backyards. This led to a decrease in soil concentration of As, Pb, Co, and Sb. The areas near the building had the least concentration of these elements in the soil, and the concentration increased with increasing distance from the building. This protective effect was also dependent on the height of the building (average height 20.7 m). The concentration of Cr, Mo, Ni, and Sn decreased between 1.3 and 1.9 times in the area between high buildings; (ii) densely built high-rise buildings can act as dust traps and increase the contaminants concentration in the inner areas. They sharply decrease the wind speed which leads to dust deposition. This effect caused an increase in the concentration of Cd and Cu in the soils (Kosheleva et al. 2018).

HMs concentration in urban soil is an important geochemical tracer to identify anthropogenic influence. Al-Khashman and Shawabkeh (2006) studied soils near a cement manufacturing plant in Jordan to determine the impact of human influences on HMs presence. They collected soil from the surface at depths of 0–10 and 10–20 cm. They observed high concentrations of Pb, Zn, and Cd in the soils which they attributed to the traffic emission and emission from the cement factory. The metals were also found to be concentrated in the surface layers and decreased with increasing soil depth. Soil contamination was observed in playgrounds in Colombia and Norway by Donado et al. (2021) and Ottesen et al. (2008), respectively. Donado et al. (2021) observed high concentrations of arsenic (As) (26 mg/kg), Ni (10.8 mg/kg), Cu (39 mg/kg), and Pb (89 mg/kg) in the playgrounds. They determined the source of the HMs to be intense construction and industrialization, coal combustion, smelting, and traffic sources near the playground. Ottesen et al. (2008) reported high concentrations of Pb, Cd, Hg, Zn, and PAHs in the surface soil due to the effects of urbanization. The soil at depth of 4–5 m was relatively less contaminated. Higher HMs contamination was observed in soils from old and densely populated areas as compared to the younger settlements. High concentrations of As were seen in playgrounds making use of Cu–Cr–As (CCA) treated wood. Soils have been known to act as geochemical barriers and buffer HMs contamination. Romzaykina et al. (2020) undertook soil studies in Moscow city to determine the HMs concentration in urban soil and the ability of different soils to act as a buffering agent. HMs like Cu, Zn, Pb, Cd, and As were found to be 2–5 times higher than the background values and originated from industrial and traffic sources. Soils were found to be more effective barriers for Ni and Pb as compared to Zn, Cd, and As. Alkaline soils with loamy texture in the city center were better buffers than acidic or loamy sandy soils or soils covered with vegetation.

All PCBs are man-made, there are no natural ones. They were used in buildings in concrete, plaster, joint sealing materials, glue, and paint. High levels of PCBs have been found in building caulking material and in expansion joints of old buildings. They were also used in polyvinyl acetate (PVA) to improve endurance, flexibility, and resistance to erosion in concrete and plaster. Herrick et al. (2007) reported PCBs concentration in buildings with undisturbed caulking to be 10,000–36,200 mg/kg. The corresponding soil PCBs around these buildings ranged from 3.3 to 34 mg/kg. Buildings with the highest PCB concentration contributed the maximum PCB to the soil. The highest PCB concentrations were in the soil near the buildings, and the concentration decreased with increasing distance. They concluded that weathering of caulking could be an important factor contributing to the soil PCB concentration, which are leached as complexes with OM. Andersson et al. (2004) reported a similar finding on PCB emission in building materials in Norway. PCB in the building plaster ranged from undetected to 290 mg/kg, while the corresponding soil contained up to 320 mg/kg. In this study, the PCBs used in the buildings displayed a greater presence in the corresponding soil, contributing to high levels of soil contamination. The PCB level decreased with distance from the building and depended on the type of building use. Offices and industrial buildings had lesser soil PCB while residential buildings and schools were more contaminated. This phenomenon was explained by the renewal of soil and refurbishing of exteriors in the residential areas and schools. The PCB was retained to a greater extent in these soils due to their high OM. Caulking materials and plasters are generally disposed of in landfills, which could cause high levels of PCBs in the leachate, and therefore need to be reconsidered prior to disposal (Andersson et al. 2004; Herrick et al. 2007).

PAHs originate from the combustion of fossil fuels, vehicular emissions, waste incineration, urban wastewater drainage, and manufacture of chemicals, while phthalate esters arise from emissions from construction materials, furniture, plasticizers, industrial processes, and cosmetics. They are attached to particulate matter due to their hydrophobic nature and are deposited on urban soils through long-range transportation and deposition of particulate matter. They are known carcinogens and have low biodegradation in soils (Fazeli et al. 2019; Ferreira et al. 2018). A study was carried out by Fazeli et al. 2019 in an urban area in Tehran to determine the source of PAHs and their co-occurrence with HMs. The anthropogenic fraction in the metals was in the following order: Cd (87.87%) > Cr (40.14%) > Ni (38.64%) > Pb (37.40%) > Co (8.42%) > Cu (7.98%) > Zn (5.57%) > Mn (3.94%). The PAHs in the samples ranged between 0.62 to 3.51 mg/kg, had high molecular weights, and originated from the combustion of petroleum, traffic, and heating systems in houses. The authors reported that both PAHs and metals shared a common origin based on their spatial distribution.

Human activities can increase exposure to natural sources of radiation. Materials used in the construction industry are usually contaminated with natural radioactive materials like radium, thorium, and potassium. Certain raw materials like granite and slate contain a higher content of radionuclides than soils. These materials like granite or marble are used in flooring, and others like kaolin, feldspar, and zircon are used as mixtures. The presence of a significant amount of radioactive materials in buildings can increase radiation exposure. The presence of natural radionuclides in raw building materials is controlled by soil composition and source, density, water content, permeability rate. As compared to undisturbed earth's crust, building materials can increase the gamma exposure due to their geometry. Some building materials and existing buildings can increase the radon generation in closed spaces despite the fact that radon is emitted mainly from the soil (Popovic et al. 1996; Todorovic et al. 2015).

12.7.5 *Impact of Construction and Demolition Waste on the Soil During Disposal*

Table 12.3 summarizes some of the construction-related effects on soil. Waste during the construction phase arises due to misuse or mishandling of materials or due to the procurement of excessive raw materials which are not utilized ultimately. Demolition

Table 12.3 Negative impacts of construction activities on the soil

Type of land use	Soil degradation process	References
Existing residential buildings	• Destruction of natural vegetation • Increased soil compaction • Loss of soil microbial activity and fertility • Increased stormwater runoff due to sealed soil surface Increase in flash floods • Decreased in water percolation to groundwater aquifers • Increased evapotranspiration	Ferreira et al. (2018) Jie et al. (2002)
Roads, railways, airports, and transport-related structures	• Soil degradation and compaction due to use of heavy machinery • Alteration in water runoff due to the sealing of soil by asphalt or concrete, or recycled aggregates	Babak (2017) Douglas and Lawson (2003)
Mines, smelters	• Soil acidification or alkalization • Biological degradation	Artiola et al. (2019)
Landfills	• Soil compaction • Nutrient loss and fertility reduction • Destruction of naturally thriving microbes • Soil and groundwater pollution from leachate loss	Jhamnani and Singh (2009)

waste is generated through the breaking down and removal of old unusable structures (Ginga et al. 2020). C and D waste is an environmental issue worldwide, due to multiple negative impacts like contamination of soil and water resources. The impact is observed in economic terms too due to the loss of resources like raw materials and energy consumption. It affects the gross domestic product (GDP) of the country and inhibits tourism. It also affects socially by posing potential health risks. Though much of the C and D waste is inert, it contains various toxic substances like heavy metals, organic pollutants, and organic matter, which pose potential health risks. Despite the presence of only a small amount of such pollutants in the C and D waste they are a major concern for the environment due to their susceptibility to microbial activity and release under acidic conditions. These wastes also undergo microbial breakdown in landfills, releasing gas and leachate which further impact the soil (Qiang et al. 2015; Rodríguez-Robles et al. 2015). Heavy metals in C and D waste originates from sources like hazardous building materials (paints containing heavy metals or wood treated with preservatives), heavy metals contaminated soil, and from leaching of toxic elements (Qiang et al. 2015)/(Townsend 2004). The presence of these pollutants in the C and D waste has a negative impact on their re-use. But the removal of these toxic wastes at the site of demolition requires an ample amount of time and effort on part of the management (Qiang et al. 2015). Percolation of water through the wastes in landfills results in leachate carrying dissolved or suspended contaminants, and even high organic matter content in case of new landfills. The composition of the leachate depends on the type of waste and its composition, age, temperature, oxygen availability, and presence of water near the landfill. This leachate migrates into the underlying soil and groundwater and pollutes it, which not only disturbs the natural state of soil but also acts as a potential health risk. Landfill leachate also contains a high amount of metals like Mn, Cu, Pb, Zn, and Cr. Landfill soil contamination with heavy metals occurs due to the leachate flow from untreated waste disposal, and due to incinerated waste as well (Kanmani and Gandhimathi 2013; Dregulo and Bobylev 2020).

12.7.6 Risk Assessment

HMs arising from anthropogenic activities like construction are a prominent source of environmental pollution since they affect the ecology. Determination of HMs in urban soils helps in monitoring pollution (Al-Khashman and Shawabkeh 2006). Risk assessment is done to identify the potential impact of HMs on the soil. It is calculated by the Contamination factor (CF) and Geo-accumulation index (GI). CF is used to study the source and level of contamination in the soil. It is calculated as;

$$CF = \frac{C_i}{B_i} \tag{12.1}$$

where, C_i is the metal concentration in soil and B_i is the background value in absence of any anthropogenic influence. CF < 1 indicates low level of contamination, 1 < CF < 3 indicates moderate contamination, 3 < CF < 6 represents contaminated soil, and CF > 6 denotes highly contaminated soil (El-Sherbiny et al. 2019).

GI helps identify the source of contaminant and the degree of contamination. It is calculated as;

$$GI = \log_2(C_n/1.5B_n) \tag{12.2}$$

where, C_n is the metal concentration in soil, B_n is the background value of the metal in soil, and 1.5 is the constant used for potential variability in reference value. GI was divided into seven classes by Muller: GI ≤ 0 (unpolluted soil), 0 < GI ≤ 1 (unpolluted to moderately polluted), 1 < GI ≤ 2 (moderately polluted), 2 < GI ≤ 3 (moderately to strongly polluted), 3 < GI ≤ 4 (strongly polluted), 4 < GI ≤ 5 (strongly to extremely polluted), GI > 5 (extremely polluted) (Ihedioha et al. 2017).

12.8 Effect of Construction Activities on Urban Agriculture and Health Risks Due to Contaminated Soil

Urban agricultural projects have been expanding since the beginning of the millennium, from aquaponics, greenhouses, to permaculture, with various alterations in the way food is grown. Urban agriculture plays a positive role in the environment, economics, society, and nutrition, but it is crucial to identify the potential health risks associated with agricultural production in urban settings (Aubry and Manouchehri 2019). Urban soils are influenced by multiple factors. Toxic substances end up in soils as a result of anthropogenic activities. Some substances such as fertilizers and pesticides are deliberately added to soils to improve crop production, while others like industrial and commercial chemicals cause contamination through leakage or spills. Contaminants can also spread through the air and reach soil by precipitation or dust settlement (Turner 2009). Humans in close contact with contaminated materials and soil are at an enhanced risk of potential health issues (Swartjes 2015).

12.8.1 Effect of Dust and Heavy Metals on Plants

Cement manufacture produces a lot of dust which spreads to a wide area due to aeolian activity. This dust pollution affects photosynthesis, respiration, and transpiration in vegetation growing in the vicinity of the manufacturing plant. Dust can settle on the leaf surface and alter growth and stomatal opening, or it can get absorbed into the plant and inhibit essential nutrients uptake. When this dust settles on plants it disrupts the physiological and biochemical processes in plants. It induces the production of reactive oxygen species, resulting in oxidative stress in plants. Cement dust contains calcium hydroxide which denatures the leaf proteins (Semhi et al. 2010). Dziri and Hosni (2012) reported a decrease in essential oil production in pine needles when the pine plants were exposed to cement dust. They concluded that oil production was the most sensitive biochemical process in pine, which could be a result of reduced photosynthesis caused by dust covering the stomata and photosynthetic tissues, or due to an increased rate of senescence. Dust produced by the marble industry also affects the surrounding soil and vegetation, impacting plant growth due to water logging and alkalinity (Pappu et al. 2007).

Background concentrations of HMs in the soil are due to their geogenic origin, but anthropogenic influences increase their concentration, making them harmful for plants (Chibuike and Obiora 2014). These anthropogenic activities include fossil fuel burning, smelting of metals, mining, construction, municipal solid waste disposal, and usage of fertilizers and pesticides (Alloway 1995). In recent years, studies have focused on HMs contamination of agricultural soil and related health risk assessment (Kong et al. 2021). Heavy metals commonly found at contaminated sites are Pb, Fe, Al, Cr, As, Zn, Cd, Cu, Hg, and Ni (Subhashini and Swamy 2016). The effect of HM on the growth and development of plants differs with the HM involved. Elements such as Pb, Cd, Hg, and As, which do not play any beneficial role in plant growth have severe effects on the plants at very low concentrations in the growth medium (Mohnish and Nikhil 2016). Cu, Fe, Al, and Zn are essential components in plant nutrition and development. However, they induce extreme phytotoxicity at high concentrations, significantly affecting plant growth, mineral uptake, and photosynthetic activity (Abdus et al. 2016). Due to alteration in physiological and biochemical activities, plants growing on HMs polluted soils display reduced growth (Chibuike and Obiora 2014). This growth reduction can be attributed to decreased photosynthetic activity, altered mineral nutrition, and reduced activity of some enzymes (Kabata-pendias and Pendias 2001).

Soil is the most common repository for airborne pollutants, but it cannot be considered a permanent sink. Contamination of soil enhances the opportunity for contaminants to be absorbed and recycled into the human food chain through agricultural activity, home gardening, and grazing animals (Swartjes 2015). Several research findings suggest that the presence of HMs in the soil beyond a certain limit results in toxic effects on plants, animals, and soil micro-organisms (Mohnish and Nikhil 2016). The presence of metals and metalloids like As, Cd, Ni, Pb, Cr, Cu, Mo, and Se in the soil produces an antagonistic effect on the yield and nutritional quality of food crops (Ahmad et al. 2018). In order to maintain the ecological harmony of our planet, there is a need to understand the interaction of HMs with plants. HMs produces a negative effect on plants, and plants have an inbuilt defense mechanism to protect against such toxic effects. Mahmood and Islam (2006) researched the effect of Cu, Zn, and Pb on seed germination and seedling growth of barley (*Hordeum vulgare*) rice (*Oryza sativa*), and wheat (*Triticum aestivum*). The inhibitory effect of Cu on seed germination was more pronounced in rice than in either wheat or barley. The roots of the seedlings grown in control or at lower concentrations of Cu, Zn, and Pb were white, long, with abundant root hair, and long lateral roots. But at higher concentrations the root tips of all the seedlings turned brown, roots were hairless, stunted, thick, curled, and with numerous small lateral roots.

12.8.2 Indirect Health Risk from Crops Cultivated in Contaminated Soil

Employment of contaminated soils for agriculture and consumption of the resultant crops poses potential health risks for human beings and increases the probability of contaminants entering the food chain (Rutigliano et al. 2019). Agricultural land can be contaminated by dry and wet deposition of atmospheric pollutants from urban activities like construction and industrial activity (Kabata-pendias and Pendias 2001). Other possible sources of contamination are the disposal of C and D waste on soil, leakage of leachate into soil and groundwater, sewage-derived materials, and agricultural practices such as the addition of fertilizers and pesticides (Liu et al. 2013).

Usage of wastewater for irrigation has increased in urban areas. Though it helps in reducing groundwater extraction for irrigation and contains a high amount of essential nutrients and OM (Zhang and Shen 2017), this practice has several drawbacks (Murtaza et al. 2010). Wastewater contains HMs such as Zn, Cr, Cu, Cd, Ni, Pb, and Hg, which can contaminate the environment and induce severe health risks in human beings (Khan et al. 2008). The usage of untreated wastewater for irrigation can result in soil and groundwater contamination, and cause hardening of soil (Liu et al. 2017). The contamination of agricultural soils with HMs can have negative implications on human health for a very long period because HMs is persistent and non-biodegradable in soil (Khan et al. 2008). Soil quality should be monitored continuously to control the health risks arising from the consumption of crops contaminated with toxic elements (Piekut et al. 2018).

12.8.3 Daily Intake of Metals (DIM) and Health Index Risk (HRI)

The DIM is determined by the following equation (Khan et al. 2008),

$$\mathrm{DIM} = C_{\mathrm{metal}} \times C_{\mathrm{factor}} \times D_{\mathrm{food}} / \mathrm{B.W.} \tag{12.3}$$

where, C_{metal}, C_{factor}, D_{Food}, and B.W. represent the HM concentration in plants, conversion factor, daily intake of vegetables (grams), and average body weight, respectively. A conversion factor of 0.085 was used to convert the fresh weight of the food sample to dry weight.

To evaluate the health risk of HMs, it is important to calculate the level of exposure to that metal by tracing the route of exposure. Health risks arise when food crops enriched with a higher concentration of HMs are consumed by the receptor population (Ávila et al. 2017).

$$\text{HRI} = \text{DIM/RfD} \tag{12.4}$$

where, DIM is the daily intake of metal, and RfD is the reference oral dose, below which there are no observable health effects (Ahmad et al. 2018).

12.8.4 Potential Health Risks from Direct Contact

Exposure of human beings to contaminated soil may cause many health risks varying from nausea, and skin eruptions, to cancer (Swartjes 2015). High concentrations of HMs in the body can affect several organs like the blood, liver, brain, kidneys, and lungs. Long-term exposure to even low levels of HMs can result in neurological and physically degenerative processes (e.g., Parkinson's disease and Alzheimer's disease), and cancer (Brevik et al. 2020). The concentration of possible contaminants in a place depends on the land use and activity carried out there (Turner 2009). Soil despite yielding many essential nutrients can pass on harmful elements through food, and contaminated soil particles can travel thousands of miles and affect people. Direct exposure to soil contaminants can occur through oral ingestion of soil, dermal contact, and inhalation of soil particles. Thus, depending on the route, contaminants enter the body through the mouth, stomach; skin; nose, trachea, and lungs (Swartjes 2015). People working directly with soil on a daily basis like farmers, miners, and construction workers are at a greater risk of health problems. Soil ingestion or geophagy can occur intentionally or accidentally during hand-to-mouth contact particularly in children, or when vegetables or fruits are consumed without washing (Yu et al. 2019; Lindern et al. 2016). Soil ingestion is especially common in children; they are at a greater risk from urban pollutants because they play on the ground and can ingest dust stuck on their hands (Biasioli et al. 2006).

Exposure to the soil through ingestion is controlled by soil ingestion rates, concentrations of HMs, body weight, and the relative bioavailability factor in the human body. Soil ingestion rates have been determined by tracer studies, using typical soil elements such as aluminum, silicon, titanium, and yttrium in feces and urine as indicators (Calabrese et al. 1997). In rare cases, biokinetic models and Pb isotope methodology are used to estimate ingestion rates. From tracer studies, combined soil and dust intake rates range from 31 to 195 mg/day (Swartjes 2015). Skin absorption or penetration can expose a person to chemicals and dangerous pathogens in soil.

Inhalation of soil particles and mineral dust particles has been linked to a range of respiratory problems, ranging from acute inflammatory problems to fibrotic changes. Long term exposure to toxic dust can cause an irreversible respiratory disease, collectively termed as pneumoconiosis. It is caused by extended exposure of lungs to metallic or mineral dust. Inhalation of coal dust causes black lung disorder or coal worker's pneumoconiosis, quartz or silica dust causes silicosis, and asbestos dust results in asbestosis and lung disorders such as bronchitis, emphysema, and mesothelioma (Li et al. 2019; Zosky et al. 2014).

12.8.5 Effect of HMs on Human Beings

HMs also called potentially toxic elements can cause nausea, anorexia, vomiting, gastrointestinal abnormalities, and dermatitis in the human body. They may also affect the immune system and basic physiological processes (Chui et al. 2013). Cd and Pb are the most toxic elements for human health. Pb arises from traffic sources, processing of ores, and pigments, while Cd originates mainly from industries (Galušková et al. 2011). Pb severely affects and damages organs such as the kidney, liver, lungs, reproductive system, central nervous system, urinary system, and immune system and changes the composition of blood (Bansal 2018). Women are more vulnerable to the adverse effects of Cd and have a higher body burden due to increased dietary absorption of Cd in the body. Low-level cumulative exposure has been related to changes in bone metabolism and renal functions (Salt et al. 1995). Workers in close contact with Ni powder are more susceptible to respiratory cancer and nasopharyngeal carcinoma. At low concentrations, Cu acts as a co-factor for various enzymes of redox cycling (Farhan et al. 2016). However, at higher concentrations, Cu disturbs the human metabolism leading to anemia, liver and kidney damage, stomach, and intestinal irritation. Arsenic induces skin, liver, lung, and uterine cancers (Bansal 2018). Certain HMs, their sources, and related health effects are summarized in Table 12.4.

12.9 Mitigation Measures for Construction and Demolition Waste Disposal

Due to the ever-increasing rate of urbanization and re-development, new constructions are taking place which demands more landfill space. C and D wastes are bulky and take up a lot of space in the designated landfills thereby overstraining the landfill capacity. C and D wastes dumped on landfills are hazardous and difficult to remediate. To control the spread of heavy metals the landfill areas need to be stabilized and an adequate plantation cover needs to be provided (Sofilić et al. 2013). Recycling of C and D waste will help in reducing the environmental impact by: (a) reducing depletion of raw materials and natural resources, (b) less pollution due to lesser virgin resources requirement, which will reduce the manufacturing and transportation-related pollution, (c) decrease in energy requirement for all processes which will further reduce environmental damage incurred during generating energy from coal.

Table 12.4 Contaminants and their health effects on human beings

Contaminant	Source	Health effects	References
Lead (Pb)	Mining, Pb based paints, Pb–Zn smelters, solder, glass, piping	Carcinogen, damages the brain and kidneys, lowers IQ, causes miscarriage, anemia, and muscle pain, bone deterioration, and hypertension	Griswold and Ph (2009) Sharma (2017)
Copper (Cu)	Found naturally in sandstones, artificial presence is due to building materials, industrial emissions	Liver toxicity, gastrointestinal distress, headache, irritation of nose and eyes	Mahurpawar (2015)
Chromium (Cr)	Cement factory dust Metal processing industry	Causes nose ulcers, runny nose, and breathing problems such as asthma, cough, shortness of breath	Griswold and Ph (2009) Isikli et al. (2003)
Arsenic (As)	Mining and processing, wood preservatives, paints, pigments, glass, electronics industry	Chronic arsenicosis, nausea, vomiting, liver tumors, and gastrointestinal infections, various cancers, skin, heart, and liver damage, risk of miscarriage	Mohammed Abdul et al. (2015) Sharma (2017)
Zinc (Zn)	Brass and bronze alloys, rubber, tires, glass, metal coatings	Metal fume fever and restlessness	Cooper (2008) Mulligan and Galvez-Cloutier (2003)
Cadmium (Cd)	Water pipes, smelting of Zn, pigments stabilization, metal plating, Ni–Cd batteries, alloys	Carcinogen, causes lung fibrosis, liver and kidney damage, low bone density	Järup (2003) Sharma (2017)
Asbestos/Silica or Quartz/Coal	Direct exposure from asbestos mining, processing, or disposal, products like asbestos cement, textile, adhesive, roofing, flooring material, insulation, indirect exposure from clothes of mineworkers/Silica mining/Coal mining	Cancer (Mesothelioma), Asbestosis/Silicosis/Coal worker's pneumoconiosis	Noonan (2017) Li et al. (2019)
Organic pollutants (PAHs, PCBs)	PAHs from the combustion of fossil fuel, waste, vehicle emission PCBs from old buildings plaster and caulking materials	Carcinogenic Mutagenic	Fazeli et al. (2019) Andersson et al. (2004)

Alongside it will also help in reducing economic costs involved in purchasing, manufacturing, processing, packaging, and transporting raw materials. It will also generate employment for people in the recycling sector (Kumbhar et al. 2013).

To tackle the menace of C and D waste overburden there is a need to implement certain new methods (Yeheyis et al. 2013; Zhang et al. 2013);

a. **Adaptive Reuse**
It involves the process of recycling existing buildings by finding a new use for them. When buildings are structurally strong and well-built but have been discarded then they are altered and repaired and re-used (Cantell and Huxtable 2005).

b. **Regulatory Framework**
There is a need for the implementation of laws that focus on reducing the waste content of C and D waste. Outlawing the practice of landfilling certain waste materials could help retain more space in the landfills. Several countries in Europe have imposed stringent measures to reduce the disposal of C and D waste on landfills. Any demolition activity can be done only with legal permission whereby each demolished component and its disposal method needs to be specified and the demolition wastes need to be disposed of separately. Failure to do so attracts a huge penalty. The disposal of C and D waste is also taxed, while recycling is recommended and free of charge (Ponnada and Kameswari 2015).

c. **Life Cycle Assessment (LCA)**
Waste generation during construction activities occurs during the entire life cycle of the construction process. The quantity and quality of the waste is dependent on the stage of the construction. To address this waste generation and environmental degradation LCA is used as a decision-making tool. LCA methodology helps evaluate the environmental costs of the processes and products related to the entire construction process. Methodologies for determining the LCA were formulated by the International Organization for Standardization (ISO), and ISO14040 deals with the potential environmental impacts of construction-related activities. LCA is called a 'cradle to grave' system because it evaluates the environmental impact of all raw materials and processes involved in the construction like extraction of raw materials, processing, application, demolition products, and their recycling and disposal (Singh et al. 2011). It helps create a defined scope, inventory of the life cycle of products, impact assessment and interpretation of any project. LCA application in the building sector has increased since it is a major consumer of material resources and energy and generates a high amount of environmental impact. The operation stage has the highest environmental impact of 80–90% while the main construction phase has 8–20% impact.
Based on the LCA, the management of C and D waste occurs at three stages of the life cycle: pre-construction, construction, maintenance, and renovation, and post-construction (demolition). At each stage, there is the application of 3 Rs (reduce, reuse, and recycle) to ensure minimal wastage of materials. 3R's help

in conserving raw materials, saving energy, reducing pollution, and reducing the need for landfill spaces or incineration.

d. **Circular Economy**
Circular economy utilizes the idea that there is no end of life of any product and wastes are a useful resource. All materials are constantly reused and recycled at all stages of construction, reducing the wastage of raw materials during construction and minimizing the resultant waste produced (Ginga et al. 2020).

e. **Re-utilization of C and D Waste**
Re-use or recycling of C and D waste is a sustainable and viable process. Recycled products enable less demand for virgin raw materials, which helps in reducing the environmental costs and the expenses incurred during the exploration of raw material and their extraction. Less waste produced also lessens the burden on the landfills. Some examples of recycled wastes are recycled concrete bricks, crushed tiles, and glass in the form of coarse and fine aggregate, and latex paint used as a binding agent in concrete.

12.9.1 Recycling of C and D Waste

C and D wastes need to be managed properly for disposal in accordance with environmental and health considerations (Kumbhar et al. 2013). The handling involves the following steps:

a. **Separation, Storage, and Transportation**
The C and D waste need to be segregated at the site of generation because it is extremely difficult to separate them at the disposal site where they are mixed. This also helps save energy and time. Prior to this, materials like glass, plastic, and wood need to be recycled for reuse. Trucks or tractors are used to transport individual containers to the disposal site.

b. **Recycling for Reuse**
Due to the large volume of C and D wastes they cannot be composted or incinerated. They are dumped on landfills, which are growing relatively scarce due to the increased demand for land for other purposes. Disposal on landfills is not only an eyesore to the public it also has negative impacts like the release of toxic gases and pollution of the underlying soil and groundwater due to leachate. Recycling is therefore important to reduce the impact on land resources for landfilling. It will also help reduce costs involved in the extraction of raw materials, transportation, and energy utilization.

c. **Disposal**
Since C and D wastes are inert, they do not cause pollution if devoid of heavy metals or organic components. They can thus be used for leveling low-lying areas, for building a base for building construction or roads. This would help reduce the need for landfill disposal.

Despite the regulatory measures proposed for the management of C and D waste, the implementation rates are low. LCA has a high variability when applied to real-life scenarios due to the difficulty in accurate measurement of data. This uncertainty is because a large number of raw materials are involved in the construction process, and their life span extends over several hundred years. A common LCA study cannot be applied globally due to the difference in the type of raw materials utilized and due to the difference in the building structure and utilization (Hossain and Marsik 2019).

12.10 Mitigation Measures for Contaminated Soil

People living in urban environments are largely affected by pollutants from the surroundings. Pollutants in the soil can find their way to human beings through inhalation of dust or particulate matter, from the food chain when people consume plants cultivated in contaminated soil, and when children consume soil while playing with it (Galušková et al. 2011). Remediation of contaminated soil is done by removing or reducing the contaminants in the soil through methods like excavation of soil and transport to another place, chemical oxidation, phytoremediation, and thermal desorption (Sharma 2017; Scullion 2006).

These methods have been proposed to tackle the menace of soil contamination in urban areas: Removal of soil and its disposal and treatment in another area, treatment of soil at the site, and containment at the site (Gailey et al. 2020; Sharma 2017; Scullion 2006; Mulligan and Galvez-Cloutier 2003).

a. **Removal and Transport to Another Place**
   In this method, the soil is collected from the contaminated site and transported elsewhere for disposal. The void formed is filled with uncontaminated soil. Despite being the quickest method, it is not useful due to the high transportation costs involved, and due to the distribution of contaminated soil into a larger area.
b. **Chemical Oxidation**
   Chemicals are applied to the soil, either in situ or ex situ. They help in destroying the pollutants, breaking them down into less toxic forms, or rendering them immobile in the soil. The addition of liming material, alkaline biosolids, chelating agents like ethylenediaminetetraacetic acid (EDTA) and nitrilotriacetate (NTA), can help immobilize mine wastes containing heavy metals.
c. **Physical Treatment**
   Soil is treated thermally ex situ at a temperature more than 1000 °C, to destroy the organic pollutants. A high-temperature treatment called vitrification is also carried out for trapping inorganic pollutants in a solid ceramic material. But both these processes destroy the soil, and the resultant products are disposed of in landfills. Vapor extraction and air sparging are used for the extraction of materials like benzene and toluene by volatilizing them. Soil washing is another procedure done ex situ whereby more soluble pollutants are extracted based on their size, density, or surface properties.

d. **Biochemical Processes**
This involves the use of microbes and chemicals to remove heavy metals in soils. Bacteria like *Thiobacillus* sp. under aerobic conditions at sufficient temperature (15–55 °C) can oxidize metal sulfides to produce sulphuric acid, which helps in desorbing metals from the soils through the process of leaching. Another technique involves the use of the fungus *Aspergillus*, which produces citric acid and gluconic acid. These acids act as chelating agents and help in removing Cu. Bacteria like *Bacillus subtilis* and sulfate-reducing bacteria can oxidize Hg and Cd and reduce As and Fe, in presence of sulfur. Biosorption is another process that utilizes bacterial or algal cells for the adsorption of metals into their biomass. This is useful for removing a low concentration of metals in water.

e. **Soil Treatment at Site**
Contaminated soil is covered on-site with a geotextile material, which is then layered with 15 cm of relatively uncontaminated soil. This is done specially for the reconstruction of sensitive areas like playgrounds, parks, schools. But the process of procuring the uncontaminated soil is destructive for other ecosystems.

f. **Containment at Site**
This is carried out with the help of microbes through the process of bioremediation or with the help of both plants and microbes through the process of phytoremediation. Phytoremediation employs plants in ex situ or in situ for cleaning contaminated hazardous waste sites (Subhashini & Swamy 2016). Phytoextraction is the most common method of phytoremediation used for the treatment of heavy metal polluted soil (Mohnish and Nikhil 2016). Plants and microbes associated with plant roots and soil help in breaking down organic pollutants and enable greater uptake of heavy metals. These metals uptake by plants are sequestered in the plant roots or stem and leaves. This process is beneficial because it is the least invasive of all processes and does not damage the soil properties. Containment at the site is also carried out through urban gardening. Urban gardening helps in providing food, reduces storm water run-off, provides habitat for a variety of organisms in the urban environment, thus preventing their displacement, and helps in carbon sequestration. Urban gardening when carried out with the help of soil amendments like biochar, compost or P further help in containing pollutants through absorption or complexation. Application of chelating agents like organic acids also helps in rendering the heavy metals immobile. Certain plants known as hyperaccumulators tend to uptake and store high amounts of heavy metals in their plant parts. Some of them accumulate specific metals while others can efficiently uptake all metals. Plants like *Pteris*, *Trifolium*, *Silene*, *Thlaspi*, *Urtica*, *Chenopodium*, *Alyssim*, and certain species of *Brassica* are efficient hyperaccumulators. Trees like *Salix* and *Populus* are also useful in phytoremediation in areas where the pollutants are present beyond the root zone of other plants.

To ensure that construction and demolition activities cause the least damage to the environment the following issues need to be considered (Cole 2000):

- Protection of the soil and vegetation at the building site and at the site of raw materials excavation.
- Ensuring that the excavated soil is properly disposed of and covered with vegetation.
- Contaminated soil should be treated with an appropriate method according to the degree of soil contamination and should be covered properly to avoid loss of contaminated leachate.
- Prevention of storm water or run-off contamination during construction.
- Construction of green buildings and applying proper maintenance to ensure the long life of all constructed spaces.
- Generating minimum waste during construction by using recycled materials, or materials that can be easily decomposed, are environment-,friendly and locally sourced.
- Conducting demolition when necessary and recycling all components that can be salvaged and reused.
- Minimizing toxic releases to soil and groundwater during all construction and demolition processes and the life cycle of the constructed space.
- And ensuring that individuals living in the surroundings are least impacted by construction-related potential health effects.

12.11 Conclusion

Construction activities are the backbone of every developing economy. To keep up with the rapid pace of globalization construction activities are a requirement. But this industry plays a major role in the destruction of the ecosystem and environment. All processes involved in the construction sector negatively impact the environment especially the soil. Processes like mining for extraction of raw materials lead to soil acidification and desertification. Removal of sand increases the chances of floods and erodes soil. To reduce the impact of the construction processes on the environment, greater emphasis needs to be placed on the reduction of C and D waste production and recycling and re-use of such demolition wastes needs to be encouraged. This would help in reducing the energy costs incurred during incineration and reduce the burden on landfills. There is also a need to formulate stronger laws to ensure that construction companies and individuals are not involved in the misuse of natural resources. Any disobedience to follow the rules should be meted with levying of heavy fines. Soils that have been already contaminated with pollutants arising from the construction can be remediated with the help of chemicals or through bioremediation. Hyperaccumulating plants can uptake a high amounts of metals from the soil and accumulate in their plant parts. Employment of such plants can help in remediating soils without any impairment of the soil parameters. Remediation of contaminated soil is essential and obligatory for the maintenance of the soil environment and its functions. It is also vital for the health of the people living in and near all urban constructed spaces.

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