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(A No. 179) Urban Soil Health in Smart Cities

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Abstract

Urbanization is rapidly transforming cities worldwide, creating challenges for food security, climate resilience, and environmental sustainability. While smart city initiatives focus on technology, infrastructure, and resource efficiency, the health of urban soils-the most important foundation-remains critical for sustainable urban development. Healthy soils provide essential ecosystem services, including water regulation, carbon storage, pollutant filtration, and support for vegetation, urban agriculture, biodiversity and sustained good human health. However, urban soils are increasingly threatened by sealing, compaction, pollution, and contamination from heavy metals and industrial waste, which can adversely affect human health and ecosystem stability. To address these challenges, innovative strategies such as phytoremediation, bioremediation, composting and waste valorisation, and green infrastructure are being applied to restore and enhance soil functionality. By integrating these approaches into urban planning and policy, cities can improve soil health, support sustainable food production and mitigate environmental hazards. Protecting and rehabilitating urban soils is essential for creating greener, healthier, and more sustainable smart cities for present and future generations.

Urbanization is increasing rapidly across the globe, with a growing share of the world's population that shifts from villages and rural areas toward the cities. This percentage is expected to rise even further in the coming decades. About 55% of the global population now lives in urban areas, and this share is projected to reach nearly 68% by 2050. As cities continue to expand, they must deal with several challenges, including ensuring food availability, addressing climate change, managing environmental damage, and maintaining a good quality of life for residents in expense of deteriorate the natural resources and exhaust them. To tackle these issues, the idea of smart cities has gained attention, combining advanced technology, efficient infrastructure, and sustainable environmental practices to create better urban environments.

Within this framework, one important factor that is often neglected is the health and management of soil beneath our feet, which forms the essential base for sustainable urban development. Urban soils serve a much greater purpose than merely holding up buildings, roads, and infrastructure. They play an important role in creating greener, more resilient cities. By recognising the value of urban soils, planners and communities can make more informed decisions when designing homes and neighbourhoods for the future. This perspective also aligns with the one health concept, which highlights the close link between soil health and the well-being of people, animals, plants, and the broader environment.

In cities, however, soils are often altered by construction activities, compaction from heavy machinery and traffic, surface sealing with concrete, and contamination from various pollutants. Even under these conditions, urban soils continue to provide valuable ecosystem services. They help filter water, store carbon, regulate local temperatures, and support plant growth. Healthy soils also play an important role in urban farming, green infrastructure development, and maintaining biodiversity. Because of these benefits, protecting and managing soil health in urban areas is essential for creating sustainable, resilient, and environmentally responsible smart cities.

Understanding urban soil health:

Urban soil health simply means the ability of soil within city environment to perform function efficiently such as to support plant growth, regulating water flow, storing nutrients, and sustaining biodiversity. Unlike agricultural or forest soils, urban soils are influenced heavily by human activities including construction, transportation, waste disposal, and industrial operations. Healthy soils contain all the essential nutrients, organic matter, soil water, air, living community such as microbes, insects, earthworms etc. that overall increases the productive capacity of soil and provide strength to withstand in

adverse conditions. When properly managed, they can support urban greenery, filter pollutants, regulate temperature, and contribute to the overall environmental health of cities.

Here are some ways through which soil and cities are connected:

1. **Soils provide food for urban populations:** Healthy soils in urban areas contribute significantly to food production, supplying roughly 10 percent of the vegetables, legumes, and tubers consumed in cities worldwide. These soils support urban and peri-urban farming by enabling the cultivation of fresh and safe food in community gardens, small plots, and rooftop farms. Such local production helps ensure that nutritious food remains available and easily accessible within urban markets. In addition, urban agriculture plays a meaningful role in city economies by supporting local livelihoods and creating employment opportunities for urban residents.

2. **Soils can reduce pollution and temperature in cities:** Cities are the primary centre for causing traffic and industrial pollution that contaminate the soils. Actions are needed to identify, manage and restore such polluted urban soils. Integrating green spaces, tree pits and green corridors can help filter pollutants. Healthy soils in turn enable greater green coverage of the land, which absorbs less heat and cools down the surface temperatures, absorbs rainwater and reduces landslides and floods.

3. **Soil boosts human health:** Healthy soils form the base for urban and peri-urban green spaces such as forests, parks, gardens, and city trees. These green areas provide recreational opportunities and greatly support human health and well-being. Spending time in parks and around trees can reduce stress, anxiety, and depression while encouraging physical activity. When soils remain healthy and cities become greener, communities benefit both physically and mentally.

Source: https://www.fao.org/newsroom/story/healthy-soils-for-more-resilient-and-greener-cities/en

Emerging issue of contaminated soils in cities:

Due to the increasing population and expansion of industrialisation, the contamination of urban soil increasingly drastically. Although, in urban areas, continue exploitation of soil due to urbanisation, industrialisation, pollutions caused

by factories etc. generally disrupts and harm the overall health of the soil in urban areas. Due to increasing rate of urbanization, construction of buildings, roads frequently lead to soil sealing and compaction which adversely affects the physical, chemical and biological properties of soil. This increasing issue of soil health is not only an environmental issue but also has a serious threat for the human health. Several studies showed that the main reason behind the building up of heavy metal contamination in soils in urban areas was the polluted water discharged from several factories and industries without proper treatment. Urban soils often contain various harmful contaminants such as pesticides, petroleum products, radon, asbestos, lead, chromated copper arsenate, and creosote. Research shows that soils in many large cities have much higher levels of metals and metalloids than natural background levels, including elements (Cd-up to 111 ppm; Cr-up to 309 ppm; Zn-up to 1020 ppm). Other heavy metals and metalloids such as Fe, Pb, Cu, As, Ni, Se etc., are also identified in these soils in very huge amount that causing very serious diseases in the humans and also have a very harmful impact on terrestrial as well as aquatic ecosystem. Research indicates that soils in many major Indian cities contain high concentrations of heavy metals such as cadmium, chromium, and zinc, often above safe limits. In some industrial regions of Rajasthan, soil tests have reported particularly elevated levels of these pollutants, mainly because of various human activities. One of the major example of faulty human accelerated degradation of urban soil health is in Bikaner district of Rajasthan where polluted industrial wastewater that contains enormous amounts of contaminants far exceeding their safe limits are discharged into the agriculture university land area that completes destroyed such that no single green plant can grow there from the last 10- 15 years. These contaminants can cause a range of diseases in humans and also several hectares of soil destroyed.

Table: Heavy metals (mean values) in effluent, ground water and agricultural soil samples

Metals (ppm)	Effluent^{-1} (mg l^{-1})	Ground water^{-1} (mg l^{-1})	Agricultural soil^{-1} (µg g^{-1})
Cadmium (ppm)	0.014	0.006	1.927
Copper (ppm)	0.326	0.384	26.633
Iron (ppm)	0.356	2.303	44.078
Manganese (ppm)	0.167	0.402	9.900
Nickel (ppm)	0.034	0.095	7.960
Lead (ppm)	0.404	1.284	42.358
Zinc (ppm)	0.242	0.153	13.127

Source: Veena, L., Singh, R. and Jaroli, D.P. (2017). Effect of Industrial effluents on ground water and soil quality in the Industrial region of Bikaner city, India, *Indian Journal of Research*.

Pioneering strategies for urban soil health:

To address this rising challenge, India is adopting sustainable and innovative soil remediation methods. Here are some important techniques are currently being tested and applied across the country:

1. **Phytoremediation: Plant-Based Solutions for Soil Cleanup:**

Phytoremediation is an environmentally friendly method that employs specific plants to remove contaminants from soil also known as hyperaccumulators, these plants take up and concentrate heavy metals and other harmful substances. They can absorb, retain, break down, or transform pollutants, helping to restore contaminated areas and convert them into green, usable spaces. In India, plants such as sunflowers, mustard, and vetiver grass have demonstrated strong potential for cleaning contaminated urban soils. For example, *Bidens pilosa* L. can help remove cadmium, while *Pelargonium roseum* is effective at extracting nickel and lead from the soil. This method of soil improvement is cost effective and also eco-friendly. Some examples of phytoremediation are phytoextraction, phytovolatilization, Phyto stabilization, rhizofiltration etc.

2. **Composting and Waste Valorisation:** It involves recycling organic urban waste such as food scraps, yard trimmings, and other biodegradable materials into nutrient-rich compost. Applying this compost to urban soils helps restore soil fertility by replenishing essential nutrients and improving soil structure. It also increases soil organic carbon (SOC), which enhances water retention, supports microbial activity, and boosts overall soil health. In addition, diverting organic

waste from landfills reduces environmental pollution and greenhouse gas emissions, making it a sustainable strategy for both soil restoration and urban waste management.

3. Bioremediation: Microbial-Based Soil Restoration:

Bioremediation involves use of microorganisms for removal of the harmful polluted contaminants from the soil. In urban areas, soils often accumulate pollutants like heavy metals, hydrocarbons, pesticides, and industrial chemicals, which can harm plants, animals, and human health. Bioremediation helps restore these soils by breaking down toxic substances into less harmful compounds or by transforming them into forms that can be safely absorbed or immobilized by the soil. For example, Certain *Pseudomonas* bacteria can degrade petroleum hydrocarbons, oils, and other organic pollutants *Bacillus* bacteria are effective at breaking down pesticides and some heavy metals, preventing them from entering the food chain. *Aspergillus* and *Penicillium* fungi can remove heavy metals such as lead, cadmium, and chromium from contaminated soils through biosorption and bioaccumulation. This method can also be used in association with other methods.

4. De-sealing and De-compaction:

De-sealing and de-compaction are key techniques for restoring urban soils that have been covered by pavements, roads, or buildings, or compacted by heavy machinery. Removing impermeable surfaces (de-sealing) and loosening compacted soil (de-compaction) allow air, water, and nutrients to penetrate the soil, which increases the water holding capacity, improves the soil permeability, revitalizes microbial activity and supports plant growth. For example, in cities like Berlin, Germany, areas where old pavements were removed and soils were mechanically de-compacted were successfully converted into community gardens and green spaces, improving soil fertility, water infiltration, and urban biodiversity. Such interventions help restore the natural functions of soils, making them healthier and more resilient for urban ecosystems.

5. Green infrastructure (GI):

It involves incorporating elements like urban forests, parks, green corridors, and vegetated rooftops into city planning to enhance environmental sustainability. By increasing vegetation cover, GI helps manage stormwater through natural absorption, reduces the urban heat island effect by cooling built-up areas, and filters pollutants from air and water. In addition to improving soil health, green infrastructure supports biodiversity, creates recreational spaces, and contributes to overall urban resilience, making cities healthier and more livable.

Conclusion:

Urban soil health is an essential yet frequently overlooked aspect of developing smart cities. Healthy soils play a vital role in urban ecosystems by managing water flow, storing carbon, supporting plant growth, and enhancing overall environmental quality. They are also crucial for ensuring food security, strengthening climate resilience, and promoting human health and well-being. At the same time, rapid urbanization puts considerable strain on soil resources through surface sealing, compaction, pollution, and loss of biodiversity. Soil contamination with various factors affects the physico-chemical properties of soil. Due to continued introduction of heavy polluted discharges of industries, heavy metal builds up in the soil beyond their safe limit that cause serious harm to both soil as well as to the environment. For smart cities to be truly sustainable, soils must be treated as a valuable resource and integrated into urban planning and environmental policies. Various approaches such as phytoremediation, use of conditioners in the soil, bioremediation etc. used to make the soils of urban cities healthy and sustainable. By preserving and rehabilitating urban soils, cities can foster greener, healthier, and more resilient urban environments for both current residents and future generations.