Chapter 14

Urban Soil Management Challenges and Solutions

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Abstract

Soil is the basic building block of all life. Soil is an important natural resource since it serves environmental, social, and economic functions and is essentially non-renewable. Our economic and social progress is dependent on it. We rely on the soil as a physical asset in order to construct residential, commercial, industrial, transportation, and recreational sectors. Expanding urban and semi-urban regions is a primary source of soil loss. The future and resilience of densely populated areas of the world depend on the role that soils play in the abatement of climate change. Soils are the brown foundation that provides ecological services throughout urban land uses. Urban soil refers to soil that has been impacted by human activity, such as tree planting, development, pollution, and alterations to the surrounding natural landscape. Management of urban soil sealing which covers land and the substrate is a difficult topic that requires a more extensive and systematic examination of best practices, if an effective soil binding management approach is to be attained.

Keywords: Urban soil, urban soil management, soil sealing, natural landscape

I. INTRODUCTION

Urban soils are those soils that have been heavily impacted by human activities. The term does not signify the soils of urban location only. Rather urban soil consists of: (1) soils that are different from those in nearby agricultural or forest areas in terms of the materials they are made of, and that may have a surface layer of more than 50 cm; (2) soils in parks and gardens that are close to agricultural soils but have different properties in terms of composition, use, and management from agricultural soils; and (3) soils that are the result of human activity. This concept states that urban soils are essentially heavily influenced by humans in urban and suburban settings, and that these influences may have a significant impact on human health, plants, soil organisms, and water infiltration. They are distinguished from other heavily impacted soils like those discovered in remote quarries, mines, mine tailings, and airfields. However, it can occasionally be challenging to draw a distinct line between urban soils and agricultural soils. For instance, foot traffic and building activities frequently compact urban soils, which can reduce the amount of oxygen available to tree roots and prevent water and nutrient infiltration and transfer to tree roots.

Over fifty per cent of the world's population today resides in urban areas, and that number is anticipated to climb in the near future, making urban soils more and more significant. Soil properties in and around metropolitan regions can be significantly and quantitatively impacted by urban environmental influences, both direct and indirect (O’Riodan *et al.*, 2021). The urban soil continuum is formed by these influences, which range from severely affected and managed soils to essentially unmodified soils. Indirect effects involve alterations in the abiotic as well as biotic environment that have an impact mostly on undisturbed soils linked to remaining forests or grasslands, while direct effects are those typically connected with soil modifications happening on the more heavily perturbed end of the continuum. Numerous urban environmental aspects, such the urban heat island and high CO_2 levels in the atmosphere, are also comparable to aspects that are anticipated to arise as a result of global climate change.

More than half of the world's population already lives in urban settings, and some soil classification systems already define urban soils as a unique soil class with recognizable characteristics. Numerous other words are used in different soil classification systems, such as anthroposols in The Australian Soil Classification, technosols in WRB, and human-altered and human-transported soils (HAHT) in Soil Taxonomy. As a result, urban soils are becoming more significant.

II. CHARACTERISTICS OF URBAN SOIL: HOW URBAN SOILS ARE DIFFERENT FROM NORMAL SOILS

Urban soils differ from normal soils in many aspects, viz, physical, chemical, biological and ecological.

Physical	Chemical	Biological	Ecological
• No presence of topsoil or A horizon • Greater spatial variability in terms of texture and soil moisture • High compaction • Presence of artifacts like glass, plastic, animal waste, ash, wood, charcoal, pottery metals, etc	• Heavy metal contamination (Pb, As, Hg) • Salt accumulation • Low SOM	• Changes in soil fauna and microbes • Variable soil C pool and fractions • Presence of antibiotics and other pharmaceuticals	• Biogeochemical cycles (C, N, P, and H_2O) alteration • Changes in energy balance • Greenhouse gas emission

Due to the compaction, urban soils possess platy kind of structure or no structure at all. The porosity or the pre spaces are reduced, so, bulk density is often higher than normal soils or bare soils. There is no space for the exchange of air and water between soil-atmosphere interface, and thus plant roots can't grow properly in urban soils. Compaction also has a significant impact on other soil physical characteristics, such as soil structure destruction, loss of total along with air porosity, decreased infiltration rate, saturated hydrologic conductivity, and decreased effective water content and water modifying ability (Yang *et al.*, 2006). Urban soil development procedures could include clearing vegetation, removing top soil, stockpiling, compacting, and building constructing, all of which have a significant impact on soil aggregation (Wick *et al.*, 2009).

Some urban soil traits may prevent trees from growing. For instance, foot traffic and building activities frequently compact urban soils, which can reduce the amount of oxygen available to tree roots and prevent water and nutrient infiltration and transfer to tree roots. A large number of studies indicate that the pH of urban soils ranges from slightly to very severely alkaline (Lal *et al.*, 2017). The filling or dumping of materials including architectural wastes, such as concrete as well as cement, which supply a sizeable amount of $CaCO_3$, is to blame for the comparatively elevated pH levels of the soil in urban areas. Due to runoff from roads and buildings, urban soils also frequently have greater amounts of 'heavy' metals and other contaminants (Scharenbroch *et al*., 2005). Strong spatial heterogeneity is a characteristic of human-made soils, which is brought about by churning of the original soil material in places like gardens, parks, and cemeteries, as well as the numerous inputs of produced materials (such brick pieces, compost, or toxic wastes). Another category of man-made soils is mine or quarry soils, which are likewise heavily influenced by humans but are typically found outside of cities.

In less contaminated urban soils compared to more polluted ones, the overall amount of microorganisms, cellulosic degradation, and respiration (CO_2 synthesis) rates were also higher. In terms of enzymatic activities, especially dehydrogenase and urease were found to be lower in the non-sheltered streetside soils than in the sheltered park lawn soils (Kiss *et al*., 1998).

Urban soils hold carbon because of inputs from the suburbs, such as food, wood, raw materials, and peat. These inputs also bring a lot of organic compounds into the city. In addition, materials used in construction (such as concrete) and garbage (such as plastic, rubber, soot, and charcoal) all contribute to the buildup of carbon in urban soils. According to Vasenev and Kuzyakov (2018), this mechanism causes soil C levels to rise significantly over time, reaching 20–30 kg m^2 each century.

III. PROBLEMS ASSOCIATED WITH URBAN SOILS: CHALLENGES FOR THE MANAGEMENT OF URBAN SOILS

Urban soil sealing management can be viewed as a complicated system of processes. Spatial system components, systemic reactions, actor-specific aspects of the system, systemic structure conditions, and systemic consequences are important and intertwined system elements that must be considered for an effective soil-sealing-management approach. Because of the variety of interconnected limitations, driving forces, and players, controlling urban soil sealing might be seen as a difficult task. In the framework of controlling urban soil sealing, defining the problem must include what needs to be directed in order to set sub-targets and generate a better perspective of the situation. A multiscale approach to investigating soil sealing development revealed that a multifaceted soil sealing management approach includes multiple subdivisions that focus not only on the management of urban grey (that is, areas of built-up and paved surfaces near buildings), but also on the management of urban green space as its antagonist (such as forest, agricultural, and recreational areas). Through the integration of space-effective buildings and infill development, as well as putting an emphasis on green networks and protecting ecologically valuable green areas, urban green and grey spaces can be directed in a qualitative (protecting and developing green areas and reducing land take and new sealing) and qualitative manner.

1. Soil Compaction Problem

According to Jim (1998), compaction results in increased soil strength, which increases resistance to urban plant roots and decreases oxygen and carbon dioxide diffusion. Urban regions frequently have sealing through urban gray constructions like buildings, paving, and roads. According to estimates, 46–50% of settlement and transportation zones in typical metropolitan regions have been sealed (Breitenfeld, 2009). When compared to the neighbouring countryside, urban areas form a heat island (Landsberg, 1981). Because buildings and roadway surfaces absorb and reflect more heat than vegetation does, temperatures during the day and night are increased. The soil generally lacks the insulating quality of a layer of organic matter on the surface, and there is no continuous vegetative canopy, which keeps the amount of radiation reaching the soil at a high level.

2. Soil Alkalinity

Urban areas' alkaline soil not only causes nutrient imbalance but also alters the speciation and activity of metals, immobilizing the majority of heavy metals in the soil (Ge *et al*., 2000). Urban soils frequently acquire nitrate. Although nitrate has a short residence period in soils, the continuous addition of organic matter like manure or garbage ensures that it remains at an elevated level in urban soils.

3. Salt Accumulation

In addition, due to artificial inclusion from numerous activities, salt accumulation is frequently observed in metropolitan environments. In actuality, eutrophicated soils are more common in urban and suburban areas (Zhang *et al*., 2006).

4. Heavy Metal Pollution

Numerous studies have demonstrated that urban soils have higher concentrations of heavy metals than nearby agricultural as well as forestry soils. Urban soils tend to be sinks for persistent organic contaminants such PCBs, PCNs, and PAHs. All of these organic pollutants reach urban and suburban soils primarily by air deposition and waste disposal, and their level of concentration in soil relies on how much of them are present in the atmosphere or in the garbage, as well as how the soil's physical characteristics affect how they are transformed in the soil. Animals are frequently vulnerable to fluoride toxicity due to the high levels of pollution in the soil, water, and feed from industrial effluents released near NALCO units in Odisha (Jena *et al*., 2003). In West Bengal, a total of 88.750 km^2, including 9 districts have been designated as an As contaminated zone (Santra *et al*., 2013; Meena *et al*., 2023). Because of irrigation from highly selenium-containing ground water, se toxicity is detected in the north-eastern part of Punjab (Nayyar *et al*., 1990). High concentration of heavy metals, low OM and high pH in urban soils results in decreased enzyme activities (Xian *et al*., 2014; Yang *et al*., 2015)) and endanger living organisms (Nanmomi *et al*., 2014).

5. Altered Microclimate

Urban soils have altered micro climate, have higher vapour pressure deficit which may cause higher transpiration, moisture stress and reduced photosynthesis in urban cropping systems (George *et al*., 2007). The majority of urban areas exhibit "heat islands" behavior as a result of the huge quantities of heat that are retained and reflected off paved or if not covered areas, such as roads, highways, sidewalks, parking lots, building rooftops, and facades, as well as the generation of heat energy within the area by means of commercial, industrial and residential processes (Landsberg, 1981; Vittum, 1974). Additionally, because cities have so much covered territory, there is less open ground and flora, which often has a cooling impact. The combined effect of these factors raises air and soil temperatures over what is often predicted for the region's native soils (Halverson and Heisler, 1981), which puts more moisture stress on urban vegetation, but also the air temperatures, thereby increasing the moisture stress on the urban vegetation and often leading to reduced vigour (Bassuk and Whitlow, 1985).

The form as well as accessibility of nutrients are largely influenced by the soil response, also known as pH. The diversity and activity of the soil's microbial populations, which are essential to numerous nutrient activities, are similarly impacted by soil response (Alexander, 1980). The fact that a lot of the water in urban centers runs over man-made things like asphalt, concrete, and brick complicates issues. According to Bryan (1972), Halverson *et al*. (1982), and Owe (1981), when the water travels, it dissolves materials from such surfaces and also accumulates others from the buildup of air pollution. When these materials react in the soil, the pH of the soil is often raised. The raised soil pH may have negative impacts on other species, especially acid-loving plants like rhododendrons, such as nutrient deficits and enhanced toxic-substance solubilities, rendering soil management a challenging issue (Moore, 1974).

6. Nutrient Cycling Disruption and a Lack of Soil Microorganisms

Trees and bushes periodically drop organic matter on natural soils in the form of branches and foliage. These organic residues are broken down by a variety of creatures that live in the soil, and the energy and nutrients they carry are released for use by the organisms and the surrounding flora. These cycles are broken in urban soils by a number of variables, including the frequent sweeping of leaf litter as waste and the low biomass production of the plants, which results in relatively little litter falling on urban soils. The variety as well as activity of soil microbes in urban soil are decreased below optimal levels as a result of the lack of organic matter.

7. Existence of Artificial Materials

The majority of urban grounds contain various types of man-made elements, including brick, asphalt, wood, metal, glass, and plastic. The ingredients have a variety of consequences for the soil and any potential growth. On the one hand, they can physically prevent root infiltration, water flow, and gaseous diffusion; on the other, they can have the reverse effect by causing sizable gaps that allow for excessive water drainage through the profile. In some situations, these synthetic materials may produce toxic substances during the decomposition process that are harmful to soil creatures and plants. If the soils are contaminated with heavy metals, deicing salts, pesticides, herbicides, and industrial wastes, the issues get much worse. The chemistry involved in such problems makes mitigating them difficult. Wet to dry accumulation of air pollutants, such as different hydrocarbons, their esters, and fatty acids, as well as other compounds created by burning fossil fuels, are all possible on bare soil in metropolitan settings. The soil particles are coated with these oil-based compounds, which renders them water-repellent (Jex *et al.*, 1985). This process severely inhibits or perhaps completely prevents water infiltration, which contributes to soil drought, along with crust development brought on by foot traffic on exposed soil. Fortunately, when soil is covered by grass, these water-repellent crusts don't seem to develop.

IV. URBAN SOIL MANAGEMENT SOLUTIONS

Urban soils develop and change, and the management of the natural resources in and around those regions must follow suit. Application of P-based fertilizers such as SSP, DSP, TSP, etc. (As P fertilizers are known to improve soil structure) and organic amendments; Composted bio solids and Phytoremediation; Alleviation of soil compaction by vertical mulching, trenching, soil amendments, subsoiling, etc. are all potential soil remediation strategies for urban agriculture. Multifunctional buffer stripes that increase infiltration, provide wind protection to the crops, aerosol filtration, run off as well as run in control and also yield marketable products are a good tactic to manage degraded urban soils. Ornamental, medicinal and aromatic plants can be grown too in the urban areas. The inclusion of artificial soil less culture with vertical growth that promotes efficient utilization of water and nutrients can serve as a potential management technique for urban soils, but the concept of soil less culture is still fancy to a country like India. Urban as well as agricultural waste recycling is a must to combat urban soil pollution.

1. Compaction Correction

Preventing compaction is the best defense against it. The careful planning (and scheduling) of setup and upkeep procedures can achieve this. It is essential to dislodge the soil by rototilling, disking, and loosening with a backhoe shovel if the soil begins to compact during construction before respreading topsoil. In order to avoid compacting the freshly laid topsoil, the topsoil should be re-spread concurrently with the setting up of the planting stock, starting in the center or interior of the design and proceeding outward (Lehman *et al*., 2007). Certain recently discovered techniques for reducing compaction beneath trees or other established plants can be challenging to apply without causing considerable root system damage. Two devices that were recently tested "explode" air through the soil at depth, followed by the filling of the newly produced voids with vermiculite or a similar substance. Studies on loosening the subsurface have produced conflicting outcomes (Smiley *et al*., 1990). Watson presents an excavation and compost-backfilling procedure that is said to be based on an antiquated Chinese technology and might be effective. Aeration methods that were first created for playing fields and golf courses are applicable to turf regions.

2. Drainage improvement

Any design must take both surface and subterranean drainage into account. Surface drainage has the potential to either transport necessary water out from a growing or surplus water—often tainted with hazardous de-icing salts—into a planting. Swales, berms, & terraces, must be included in the final design grade to provide the best drainage pattern throughout the project by diverting water out of plants that are sensitive to excessive moisture. Berms are a suitable solution when drainage at a specific location is hampered by soil compaction, a high clay content, or by a thin impermeable layer. The soil specifications for the berm must be created with care. The soil should not self-compact, should stay friable when damp, should have little potential for erosion, and should be able to hold enough water relative to its volume. Unless the planting palette includes species acclimated to damp soils, subsurface drainage is necessary if the soil has little natural drainage. In order to remove surplus water from plant root systems, subsurface drainage designs typically involve the installation of tile as well as perforated plastic pipe on sloping grade at the proper depth. The site's contribution of water from precipitation throughout the dormant season and any water from runoff that seeps into the profile must be adequately removed by the drainage system. These methods have undergone extensive development by agricultural engineers and agronomists, and many of the concepts can be applied to urban soils. If the plantation is linear across a section of the street, the underdrainage can run continuously throughout the planting's whole length.

3. Amount of Soil Required for Rooting

How much volume of soil needs to be provided for each tree when planting trees in urban areas with limited space is one of the key issues. Design factors mean that it is not just a case of "the more the better." The majority of planting parameters stick to the traditional 4 feet by 4 feet by around 2 feet depth (32 cubic feet) measurements. The author has discovered many tree-planting trenches that are far smaller than these specifications, some of which are as little as 2 feet by 2 feet by 3 feet depth (12 cubic feet), sustaining extremely subpar plant specimens. Cox proposed 4 feet by 8 feet by 2 feet deep streetside tree trenches as early as 1916. According to Kopinga's (1985) research, the American elm can grow in the Netherlands with a minimum volume of 75 cubic feet, which is adequate but not optimal. In five significant eastern U.S. cities, Urban has studied the planting conditions and tree growth responses of approximately 1500 trees. He demonstrates that the largest and healthiest trees had access to around 600 cubic feet of soil, and that 300 cubic feet was the absolute minimum for those trees with sufficient vitality. It is important to realize that trees established in ideal conditions can thrive in considerably smaller spaces than 300 cubic feet. Without compacted soil nearby, open-planted trees obviously do not experience limited rooting volume.

4. Improved Drainage Systems

Various planting plans for sidewalks or paving-covered soil conditions were studied by Jewell in 1981. The vault system created for Pennsylvania Avenue at Washington, D.C., seems to be quite effective. The sidewalk's underside will be irrigated and aerated as a result of this design, which will encourage roots to grow into new soil. A 14-foot-diameter irrigated ring is depicted over soil that is 24 inches depth in the design. The rooting volume has a minimum of 307 cubic feet and could possibly be higher. For the tree roots to eventually share rooting area, the prescribed soil stretches from one tree location to the next. Rooting volume can be improved by using another linear planting method. In a proposal for Market Street in Philadelphia, Heidi Schustermann had long, straight pavement cuts made and specified backfill dirt inserted in their place. The linear pit's whole length had underdrainage, and it was connected to the storm-sewer system. As a result of the linear aperture in the pavement, more water can percolate into the ground than if the design had called for individual tree pits. The various trees can now share rooting area.

5. Usage of Perennial Grasses for Bioremediation

By collaborating with the natural forces of nature and employing well-designed gauges that need minimal upkeep, are more economical, and if constructed in the correct manner may even be more efficient over long periods of time because nature's forces can increase the structural efficiency, using nature-based solutions (NBSs) to restore deteriorated soil functions while enhancing soil quality can be a viable and effective strategy for improving ecosystem services. The use of some perennial grasses, can be a potential solution to the management of degraded and polluted urban soils (Kumar *et al*., 2016). Leguminous and perennial grasses are renowned for their ability to improve soil structure, prevent erosion, and produce the most organic matter behind, which raises the humus level. There are significant genotypic variations across different species of perennial grasses, with some accumulating larger levels of lead (also known as Pb) within their root tissue than in the above-ground biomass. Perennial grass has the capacity to accumulate greater amounts of heavy metals in their roots or rhizomes, according to these authors, but they may also play an important role in the ecological system of urban areas and have applications for the creation of parks, green buffer strips along roads, and sports fields. A study was carried out by Patrova *et al* in Bulgaria in 2022 for the Sustainable Management of Urban Soils and Quality of Life Improvements. They analysed the bioremediation capacity of different perennial grasses viz, ryegrass (*Lolium perenne* L.), crested wheatgrass (*Agropyron cristatum* L.), tall fescue (*Festuca arundinacea* Schreb), and bird’s foot trefoil (*Lotus corniculatus* L.) on urban contaminated soils and encountered a positive result.

V. CONCLUSION

Urban soils directly affect the ecosystem and the ecology through processes including heavy metal contamination, element enrichment, and compaction. The establishment of an assessment of risk system, as well as improved handling of urban soil resources, call for extensive studies on the environmental capability and critical limits of urban soil contaminants, pollutant relocation and transfer dynamics, relationship between soil, air and water, and the biological consequences of urban soil contamination. Various previous studies have revealed so much about urban soil and its properties, but still there is lacuna regarding some critical points, such as, horizon differentiation process and the time required for horizonation in urban soils, cost-effective and efficient soil amendments and soil blends for the amelioration of contaminated urban landscapes, low-cost indicators to determine pollution levels, etc. Development of scientific policies in the context of urban soil management is the need of the hour. Policies should come up with compensation fees and compensation measures for urbanization and promotion of soil less culture in urban areas. The ordinary urban population needs to be introduced to the soil-less culture techniques, and small-scale industries that support entrepreneurship are needed to prepare and market the necessary components.

References

[1] Alberty, C. A., H. M. Pellett, and D. H. Taylor. (1984). Characterization of soil compaction at construction sites and woody plant response. *J. Environ. Hort*. 2(2): 48-53.

[2] Alexander, M. (1980). Effects of acidity on microorganisms and microbial processes m soil. In Effects of Acid Precipitation on Terrestial Ecosystems, ed. T. C. Hutchinson and M. Havas. New York: Plenum, pp. 363-374.

[3] Bassuk, N. and Whitlow, T. (1985). Environmental stress in street trees. *The Scientific Management of Vegetation in the Urban Environment 195*, 49-58.

[4] Bassuk, N. and T. Whitlow. (1985). Evaluating street tree microclimates in New York City. In Proceedings of the Fifth Conference of Metropolitan Tree Improvement Alliance (METRIA), pp. 18-27.

[5] Blume, H-P. (1986). Characteristics of urban soils. In Man and the Biosphere, edited by the German National Committee. International scientific workshop on soils and soil zoology in urban systems as a basis for management and use of green/open spaces. Berlin: UNESCO, pp. 23-46.

[6] Bryan, E. H. (1972). Quality of stormwater drainage from urban land. *Water Resources Bull*. 8(3): 578-588.

[7] Cox, L. D. (1916). A Street Tree System for New York City, Borough of Manhattan. New York State Coll. of Forestry, Syracuse, bull. 16, no. 8.

[8] Craul, P. J. (1985). A description of urban soils and their desired characteristics. *Journal of arboriculture*, 11(11), 330-339.

[9] Craul, P. J. (1991). Urban soil: Problems and promise. *Arnoldia*, 51(1), 23-32.

[10] Craul, P. J. (1985a). Urban soils. METRIA 5, 45-61.

[11] Craul, P. J. (1985b). A description of urban soils and their desired characteristics. *J. Arboric.* 11(11): 330-339.

[12] Craul, P. J. and C. J. Klein. (1980). Characterization of streetside soils of Syracuse, New York. *METRIA*, 3, 88-101.

[13] De Kimpe, C. R. and Morel, J. L. (2000). Urban soil management: a growing concern. *Soil science*, 165(1), 31-40.

[14] Gilman, E. F., I. A. Leone, and F. B. Flower. (1987). Effect of soil compaction and oxygen content on vertical and horizontal root distribution. *J. Environ. Hort.* 5(1), 33-36.

[15] Guilland, C., Maron, P. A., Damas, O. and Ranjard, L. (2018). Biodiversity of urban soils for sustainable cities. *Environmental chemistry letters*, 16, 1267-1282.

[16] Halverson, H. G., and G. M. Heisler. (1981). Soil temperatures under urban trees and asphalt. USDA Forest Serv. Res. Pap. NE-481.

[17] Halverson, H. G., D. R. DeWalle, W. E. Sharpe, and D. G. Wirries. (1982). Runoff contaminants from natural and man-made surfaces in a nonindustrial urban area. In Proc. 1982 Intern. Symposium on Urban Hydrology, Hydraulics and Sediment Control. Lexington: Univ. of Kentucky, pp. 233-238.

[18] Heisler, G. M. and Brazel, A. J. (2010). The urban physical environment: Temperature and urban heat islands. *Urban ecosystem ecology*, 55, 29-56.
[19] Hillel, D. (1980). Fundamentals of Soil Physics. New York: Wiley.
[20] Himelick, E. B. 1986. Root development of trees growing in an urban environment. Illinois Natural History Survey Report No. 262.
[21] Jewell, L. (1981). Construction: planting trees in city soils. *Landscape Architecture*. 71(3), 387-389.
[22] Jex, G. W., B. H. Bleakley, D. H. Hubbell, and L. L. Munro. (1985). High-humidity-induced increase in water repellency in some sandy soils. *Soil Sci. Soc. Am. J*. 49, 1177-1182.
[23] Kopinga, J. (1985). Research on street tree planting practices in the Netherlands. METRIA 5: 72-84.
[24] Kumar, K. and Hundal, L. S. (2016). Soil in the city: Sustainably improving urban soils. *Journal of Environmental Quality*. 45(1), 2-8.
[25] Lal, R. and Stewart, B. A. (Eds.). (2017). *Urban soils*. CRC Press.
[26] Landsberg, H. E. (1981). The Urban Climate. New York: Academic Press.
[27] Lehmann, A. and Stahr, K. (2007). Nature and significance of anthropogenic urban soils. *Journal of Soils and Sediments*. 7, 247-260.
[28] Meena, S., Chobhe, K.A., Manjaiah, K.M., Datta, S.P., Golui, D., Raza, M.B., Rahman, M.M. and Naveenkumar, A. (2023). Synthesis, characterization and adsorptive performances of functionalized clay minerals and red mud for aqueous arsenic removal. *Groundwater for Sustainable Development*. 23, p.101025.
[29] Moore, D. P. (1974). Physiological effects of pH on roots. In The Plant Root and Its Environment, ed. E. W. Carson. Charlottesville: Univ. Press of Virginia, pp. 135-151.
[30] O'Riordan, R., Davies, J., Stevens, C., Quinton, J. N. and Boyko, C. (2021). The ecosystem services of urban soils: A review. *Geoderma*. 395, 115076.
[31] Owe, M. (1981). The distribution of heavy metals and petroleum residues in the soil from urban surface runoff. Ph. D. thesis, SUNY, Coll. Environ. Sci. and Forestry, Syracuse, N.Y.
[32] Patterson, J. C. (1976). Soil compaction and its effects upon urban vegetation. Better Trees for Metropolitan Landscapes Symposium Proc. USDA-Forest Service. Gen. Tech. Rep. NE-22.
[33] Pavao- Zuckerman, M. A. (2008). The nature of urban soils and their role in ecological restoration in cities. *Restoration Ecology*. 16(4), 642-649.
[34] Perry, T. O. (1982). The ecology of tree roots and the practical significance thereof. *J. Arboric.* 8(8), 197-211.
[35] Pouyat, R. V., Szlavecz, K., Yesilonis, I. D., Groffman, P. M., & Schwarz, K. (2010). Chemical, physical, and biological characteristics of urban soils. *Urban ecosystem ecology*. 55, 119-152.
[36] Reynolds, E. R. C. (1975). Tree rootlets and their distribution. In The Development and Function of Roots, ed. J. G. Torrey and D. T. Clarkson. New York: Academic Press.
[37] Rose, C. W. (1966). Agricultural Physics. Oxford: Pergamon Press.
[38] Smiley, E. T, G. W. Watson, B. R. Fraedrich, and D. C. Booth. (1990). Evaluation of soil aeration equipment. *J. Arboric*. 16(5), 118-123.
[39] Spirn, A. W. (1984). The Granite Garden. New York: Basic Books.
[40] Vittum, J. S. (1974). The physical structure of city space and its effects on microclimate and human thermal comfort. M.S. thesis. SUNY Coll. Environ. Sci. and Forestry, Syracuse, N.Y.
[41] Walterscheidt, M. J. (1984). Have we been preaching the same sermon for 60 years? J. *Aiboric*. 10(1), 9-12.
[42] Watson, G. W. (1990). Tree growth revisited. *Golf Course Management* (6), 8-10, 12-14, 16, 18, 22, 24-25.
[43] Yang, J. L. and Zhang, G. L. (2015). Formation, characteristics and eco-environmental implications of urban soils–A review. *Soil science and plant nutrition*. *61*(sup1), 30-46.
[44] Zemlyanitsky, L. T. (1963). Characteristics of the soils in the cities. *Sov. Soil Sci.* (5), 468-475.