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Impact of Solid Waste Disposal on Soil Characteristics in Selaqui, Dehradun, Uttarakhand, India

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ABSTRACT

The increase in soil quality issues induced by rapid urbanization significantly affects solid waste management. Leachate infiltration, a byproduct of waste decomposition, presents considerable risks to the soil ecosystem. This study evaluates comparative soil quality parameters at a waste disposal site and a control location in Selaqui, Dehradun, Uttarakhand, India. A total of six soil samples (three from each site) were collected from both the control and dumping sites at depths of 0-15 and 15-30 cm. Key soil quality parameters, including electrical conductivity, pH, moisture content, organic carbon, total nitrogen, available phosphorus, and exchangeable Potassium, were analyzed in the collected samples. The soil chemical properties of the dumping and control sites showed significant differences. These differences demonstrated a depth-dependent trend: 0-15 cm exhibited higher values than 15-30 cm for all parameters except pH and moisture content. Soils at the dumping site displayed elevated levels of contamination compared to the control site, highlighting the considerable impact of solid waste on soil quality. Despite this contamination, the physical and chemical properties measured at the dumping site remained within the permissible limits of the World Health Organization (WHO) for soil quality. Solid waste poses serious environmental and public health challenges, including the inhalation of hazardous chemicals, obstruction of storm water drainage systems, and associations with adverse health outcomes such as congenital anomalies, cancer, and low birth weight. Furthermore, accumulating uncollected solid waste increases flooding risks by impeding storm water runoff. A comprehensive understanding of the impact of solid waste on soil ecosystems necessitates a thorough examination of pathogenic microorganisms and soil microbial populations.

Key words: Solid waste, Dumping site, Control site, Soil, Physicochemical properties, Leachate

INTRODUCTION

Soil is one of the most vital components for sustaining life. One pressing environmental issue, particularly in developing nations, is the threat of soil pollution (Chabukdhara and Nema 2012). Understanding this issue is essential for assessing soil health. The abundance and internal dynamics of soil properties determine its functional richness, while external environmental factors can significantly influence soil quality. Sojka and Upchurch (1999) point out a common misconception surrounding soil quality due to its relationship with sustainability. The rise of industry and urbanization, coupled with changing consumer preferences and living standards, has increased solid waste. Rapid urban growth has exacerbated solid waste generation, adversely affecting soil conditions. Municipal solid waste (MSW), commonly called garbage or trash, is increasingly prevalent in developing countries, especially in areas lacking proper waste management systems (Cointreau 1982, Doan 1998, Singh et al. 2011). In India, Municipal Solid Waste (MSW) management has emerged as a significant urban challenge, with many developments noted in recent years (Joshi and Ahmed 2016). According to the Central Pollution Control Board (CPCB) (Anonymous 2013), India's per capita waste generation has surged significantly, rising from 0.26 to 0.85 kg per day. Alarmingly, approximately 80-90% of municipal waste is disposed of in landfills without scientific management practices, leading to open burning and subsequent pollution of air, water, and soil (Ahluwalia and Patel 2018). Additionally, managing municipal solid waste at landfill sites can result in groundwater contamination through leachate formation, which may also contribute to releasing hazardous greenhouse gases (Ngwabie et al. 2019). A direct relationship has been established between precipitation and the seasonal variation of leachate generation in landfills (Trankler et al. 2005). Rainwater infiltration through municipal solid waste (MSW) columns contributes to leachate formation in open dump sites. As rainwater permeates these MSW columns, a clear correlation between precipitation and seasonal fluctuations in leachate production emerges (Trankler et al. 2005). These waste dumps produce leachate that infiltrates underground aquifers, thereby contaminating groundwater. Leachate composition includes trace metals, inorganic substances, dissolved organic matter, and xenobiotic organic compounds. Leachate contaminants, such as organic materials, ammoniacal nitrogen, and trace elements, pose significant threats to the ecosystem (Paul et al. 2019, Yusof et al. 2009). According to Dutta et al. (2019), heavy metal contamination is a major concern in urban areas, primarily due to the leaching of waste from landfills, which contain hazardous metals like lead, mercury, and copper. Soil contamination is one of unsanitary solid waste disposal's most serious environmental risks. The leachate from waste dumping leads to soil and groundwater contamination (Pelegrini et al. 2007, Ande and Onajobi 2009, Igwe et al. 2017). Additionally, biodegradable waste creates breeding grounds for mosquitoes, houseflies, rats, cockroaches, birds, and stray animals, thus serving as passive vectors in the transmission of diseases. It has become evident that improper waste disposal practices contribute to global warming (Jilani and Rashid 2020).

It has been documented that human exposure to toxic metals through the food chain can lead to various health issues, including blood and bone disorders, kidney damage, reduced mental capacity, and neurological impairments (Hughes 1996, Alissa and Ferns 2011). Notably, soil serves as a primary recipient of solid waste, which interacts with the soil system and subsequently alters its physico-chemical properties and overall quality (Piccolo et al. 1997). According to Anikwe (2000), soils amended with waste show a higher organic matter content. Soil organic matter plays a crucial role in influencing the degree of aggregation and the stability of soil aggregates (Mbagwu and Piccolo 1990). It can lower bulk density and enhance total porosity and hydraulic conductivity in heavy clay soils, although the extent of these effects depends on the application rate (Anikwe 2000). The importance of soil organic matter, or organic carbon, is widely acknowledged as a key indicator of soil quality (Piccolo et al. 1997, Chabukdhara and Nema 2012). In Dehradun, Selaqui is emerging as a growing industrial hub in Uttarakhand, India. The region hosts various industries, including pharmaceuticals, decorative arts, floriculture, and horticulture, which dispose of their solid waste nearby. This method of waste disposal raises significant concerns due to its contribution to land pollution when discarded openly, water pollution when stored in low-lying areas, and air pollution when incinerated. Rapid urbanization and population growth have exacerbated solid waste generation and environmental pollution. In Dehradun city, approximately 250 metric tons of solid waste is produced daily, leading to heightened public health risks and environmental degradation (Gupta et al. 2021). Consequently, the present study aims to investigate and compare the soil quality parameters of dumping sites with those of control sites and assess solid waste's impact on human health in Selaqui.

MATERIAL AND METHODS

Study area

Selaqui is located approximately 30.5 km from the clock tower and along the Chakrata road to the west of Dehradun's central metropolis. At an elevation of 635 m, it lies between latitude 30°21'40" N and longitude 77°50'44.8" E. The region is currently experiencing rapid industrialization. Unfortunately, this progress has significantly degraded the area's natural beauty, environment, and ecology due to indiscriminate and unscientific exploitation of land and underground resources. The proliferation of human settlements has had a profoundly negative impact on the local environment.

Soil sampling

Soil samples were collected during the spring season from two distinct sites - the dumping site and the control site - located approximately 4 km apart in the Selaqui block of Dehradun. Before sampling, plastic bags and other solid waste were removed from the surface. Soil samples were collected from the dumpsite at two depths (0-15 and 15-30 cm). At both sites, random soil samples were taken from two distinct depths at three different points. A total of six samples from each location (dumping and control sites) were obtained by replicating the three sampling points. The composite samples were appropriately labelled and stored in sealed plastic bags. After air drying at ambient temperature, the samples were sieved in the laboratory using a stainless-steel sieve with a mesh size of less than 2 mm.

RESULTS AND DISCUSSION

Electrical conductivity

At the dumping site in Selaqui, the electrical conductivity (EC) values range from 0.02 to 0.05 dS/m, with an average of 0.033 dS/m. In contrast, the control site shows EC values between 0.01 and 0.05 dS/m, averaging 0.025 dS/m (Table 1). These observations indicate that the dumping site exhibits higher electrical conductivity than the control site. Similar findings were noted in the Vellore dumping yard (Uma et al. 2016). An electrical conductivity reading of less than 1 dS/m indicates non-saline soil, which generally does not adversely affect most crops or soil microbial processes (Table 1). Conversely, readings exceeding 1 dS/m are classified as saline, potentially disrupting essential microbial functions such as nitrogen cycling, the production of nitrous and other nitrogen oxides, respiration, and decomposition. Saline conditions can also contribute to increased populations of plant-parasitic nematodes and heightened nitrogen losses.

pH

Soil samples collected around the dumping site exhibited pH values ranging from 6.82 to 7.69, averaging 7.37. These values fall within the acceptable range of soil quality standards (Table 1). The pH level serves as a direct and straightforward indicator of the chemical condition of the soil, with optimal nutrient availability for plants occurring at a pH of 6.5 (Praveena and Rao 2016). According to Oyedele et al. (2006), the natural pH range of soil typically lies between 7 and 8.5, with variations influenced by factors such as temperature, biological activity, and the effects of municipal waste disposal. A study by Bahukhandi et al. (2020) in Dehradun reported soil pH values between 6.50 and 7.69, with an average of 7.2. Such pH levels could indicate soils rich in metallic content. In comparison, the pH values of soil samples taken from the control location ranged from 6.66 to 6.93, with a mean of 6.80 (Table 1). Notably, the dumping site exhibits a higher pH than the control site. This elevated pH may be attributed to the presence of soluble sodium and bicarbonate ions, which can cause the precipitation of calcium and magnesium carbonates during evaporation (Deshmukh and Aher 2016). Furthermore, research indicates that the pH of contaminated soil near a municipal solid waste disposal facility in India decreases as leachate concentration increases (Pillai et al. 2014).

Moisture content

Soil moisture levels indicate the presence of leachate from disposed solid waste. Insufficient leachate production leads to moisture evaporation during summer, resulting in soil contamination. The moisture content near the dumping site varies between 9.89% and 14.28%, with an average of 12.28%, which falls within permeable limits. In comparison, the control site shows a moisture content range of 2.6% to 15.16%, with an average of 8.19% (Table 1). The acceptable moisture content is recognized to be between 11% and 17% (Oyedele et al. 2006). The lower moisture content at the control location suggests that the breakdown of organic waste contributes to increased soil humidity. Waste cover has been shown to reduce soil evaporation (Krishna et al. 2016). Samples from uncontaminated soil typically contain less moisture compared to contaminated ones (Sharma et al. 2010). Moisture levels below 20% cannot sustain bacterial activity or enhance gas production, thereby limiting the microbial decomposition of landfill gas (Avinash and

Table 1. Selected physicochemical properties of soils at study sites

Parameters	Dumping site		Control site		Soil quality standard range
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	
Electric conductivity (dS/m)	0.043 ± 0.005	0.011 ± 0.005	0.026 ± 0.02	0.026 ± 0.015	Normal <1, Medium 1-3, Harmful > 3
pH	7.59 ± 0.09	7.20 ± 0.33	6.74 ± 0.17	6.86 ± 0.015	Normal < 6.5, Medium 6.5-8.2, Alkaline > 8.2
Moisture content (%)	11.83 ± 1.74	12.73 ± 2.27	0.22 ± 6.69	9.42 ± 5.34	
Organic carbon (%)	0.69 ± 0.09	0.45 ± 0.07	1.27 ± 0.21	1.08 ± 0.11	Low < 0.5, Normal 0.5-0.75, High > 0.75
Total nitrogen (mg/kg)	487.6 ± 27.83	420.4 ± 91.08	328.2 ± 82.38	233.17 ± 46.89	
Available phosphorus (mg/kg)	62.02 ± 24.58	57.11 ± 28.88	44.42 ± 7.06	70.78 ± 32.97	Low < 28, Normal 28-56, High > 56
Exchangeable potassium (mg/kg)	256.5 ± 40.62	254.8 ± 75.16	215.23 ± 53.6	221.5 ± 29.65	Low < 140, Normal 140-280, High > 280

Mishra 2023). Soil moisture is crucial for weather patterns and precipitation, as it facilitates the dissolution of salts and influences water and heat transfer between the land and the atmosphere (Vanlalliantluanga et al. 2019).

Total organic carbon

Total organic carbon (TOC) levels near the Selaqui dumping site range from 0.38% to 0.80%, with an average of 1.18%. In contrast, the control area exhibits values between 0.71% and 1.18%, averaging 0.93% (Table 1). The dumping site contains a higher concentration of organic carbon than the control site. Organic carbon enters the soil by leaching decomposing plant and animal materials, root exudates, microbial activity, and soil biota. Statistical analysis reveals significant variations across different locations. Enhancing soil organic carbon (SOC) is essential for maintaining soil quality and mitigating climate change; therefore, SOC monitoring is critical for effective policy implementation at the agricultural level. A decrease in SOC negatively impacts soil's physical resistance and resilience. Higher SOC content improves soil fertility and quality (King et al. 2020), making it an environmental and agronomic priority. According to Johannes et al. (2017), the ratio of SOC to clay is crucial in determining soil structure vulnerability. This ratio should not fall below 10% for the soil structure's resilience.

Total nitrogen

The total nitrogen concentration at the dumping site ranges from 362.7 to 525.4 mg/kg, with an average value of 454.03 mg/kg. In contrast, the control site shows a nitrogen range of 202.2 to 420.7 mg/kg, yielding a mean of 246.98 mg/kg (Table 1). Throughout the study period, total nitrogen content was consistently higher at the dumping site compared to the control site. This disparity suggests that the composting of nitrogen-rich waste within the soil at the dumping site contributes to its elevated nitrogen levels. The addition of municipal solid waste increases the total nitrogen concentration in the soil, a finding supported by several studies (Hossain et al. 2017, Bhattacharyya et al. 2003, Montemurro et al. 2006, Walter et al. 2006, Zhang et al. 2006, Hargreaves et al. 2008). Elevated nitrogen levels in the soil facilitate the conversion of organic nitrogen into mineral nitrogen, making it available for plant uptake. However, excessive nitrogen in coarse-textured soils can lead to nitrate leaching from plant roots into nearby streams. Conversely, intermediate nitrogen levels can effectively balance plant nitrogen availability while minimizing the risk of leaching. It is important to note that the optimal nitrogen input varies depending on the clay content of the soil.

Available phosphorus

The available phosphorus at the dumping site ranges from 31.32 to 89.3 mg/kg, with an average concentration of 59.56 mg/kg. In contrast, the control site shows phosphorus levels between 32.71 and 89.92 mg/kg, averaging 57.60 mg/kg (Table 1). Phosphorus enters the soil through fertilizers and is quickly converted into forms unavailable to plants as microorganisms transform soluble phosphate into insoluble compounds. Managing phosphorus levels is essential for maintaining plant nutrient balance and promoting healthy crop growth (Wagh et al. 2013). Throughout the study, available phosphorus was consistently higher at the dumping site compared to the control site, likely due to the composting of phosphorus-rich leachate from household waste. The increase in phosphorus availability resulting from municipal solid waste contributes to improved soil fertility (Mbarki et al. 2008). Phosphorus is vital in plant nutrition, supporting photosynthesis, energy transfer, and glucose metabolism. Its availability in soil is influenced by pH and mineral concentrations, with optimal levels occurring between 6 and 7 (McGeehan 2012).

Exchangeable Potassium

Exchangeable Potassium levels at the Selaqui dumping site range from 170.2 to 313.9 mg/kg, with an average of 255.68 mg/kg. In contrast, the control location ranges from 160.2 to 267.3 mg/kg, averaging 218.3 mg/kg (Table 1). Potassium, the second most essential macro-element for soil and conductivity, is not hazardous if available in excess. Its presence results from solid waste decomposition and is crucial for optimal plant growth. Solid waste interacts with living organisms through processes such as soil adsorption, storage, biodegradation, plant uptake, ventilation, leaching, and the attraction of insects, birds, rodents, flies, and mammals. When untreated waste is discharged into water bodies, it threatens aquatic life and the animals that depend on them. A deficiency of Potassium can hinder the efficient nitrogen and water. The study found that the dumping site had higher levels of exchangeable Potassium due to increased decomposition, Potassium leachate infiltration, particularly during the rainy season. Potassium is a vital nutrient that enhances disease resistance, promotes sturdy stalk growth, improves drought resilience, and helps plants endure winter conditions (Aktar et al. 2018, Chinyere et al. 2013, Giannakis et al. 2014). Solid waste disposal can significantly alter soil characteristics, potentially boosting soil productivity by improving moisture content, organic carbon levels, and essential nutrients. Nevertheless, a microbiological analysis is essential to ensure soil health due to the potential presence of harmful bacteria in the waste.

Harmful effects of solid waste dumping in Selaqui

As discussed in the section above, there are many negative impacts of unsustainable Solid Waste management practices on the environment and health risks linked with the dumping site in Selaqui block reflect broader global concerns. Field data from the site reveal elevated soil moisture levels, total organic carbon, nitrogen, phosphorus, and potassium, indicative of leachate infiltration and uncontrolled organic waste decomposition. These altered soil parameters show that such sites create optimal conditions for microbial proliferation and disease transmission (Furedy and Rosenberg 1996). The increased moisture content not only indicates the existence of leachate but also promotes pathogen survival and the reproduction of disease vectors such as mosquitoes and rats, consistent with community reports of vector-borne diseases such as malaria and dengue. Similarly, larger amounts of nitrogen and organic carbon, while occasionally good for short-term fertility, hint to unchecked nutrient loading, which can lead to eutrophication and groundwater contamination The documented rise in respiratory and skin ailments, allergies, gastrointestinal disorders, and other health issues among residents corresponds with the site's degraded physicochemical soil quality and the presence of harmful pollutants, as suggested by the studies of Alam et al. (2013) and Appleton et al. (2006).

Furthermore, greater pH and EC at the dumping site than at the control site show changes in soil chemistry caused by the accumulation of soluble salts and waste-derived contaminants, confirming that poorly managed trash contributes to soil and water quality degradation. These findings emphasize the important need for effective waste management, environmental monitoring, and public health measures in Selaqui and the adjacent areas.

CONCLUSIONS

The comparison of soil physico-chemical parameters at Selaqui dumping site and the control site reveals considerable changes due to the impact of solid waste disposal. Electrical conductivity (EC) readings at both sites remained below 1 dS/m, indicating no immediate salt concern. Soil pH values at both sites were within acceptable limits, yet the slightly alkaline pH at the dumping site may reflect the presence of soluble salts like sodium and bicarbonates, potentially altering nutrient dynamics. The moisture content was also higher at the dumping site, likely due to leachate percolation from waste, which can enhance microbial activity and accelerate organic matter decomposition. An increase in total organic carbon (TOC), total nitrogen, available phosphorus, and exchangeable potassium at the dumping site strengthens the impact of organic waste decomposition, resulting in nutrient enrichment. While such enrichment may initially increase soil fertility, it also raises issues regarding nutrient imbalances, nitrate leaching, and potential heavy metal accumulation, which were not addressed in this work. The study's findings indicate that, overall, soil quality parameters in the examined area remain within permissible limits, except for specific locations. The analysis reveals that open dumping sites have contributed to soil contamination, and these indicators could serve as valuable metrics for assessing the need for soil remediation. This suggests that with appropriate waste management practices in designated dumping areas, certain types of waste could be repurposed to improve soil conditions. However, it is important to note that this study does not encompass an assessment of pathogenic bacteria or soil microbial populations. Therefore, the open dumping of waste may pose risks not only to soil health but also to human health and other organisms.

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