J Bangladesh Agril Univ 23(2): 141-147, 2025 https://doi.org/10.3329/jbau.v23i2.82581

ISSN 1810-3030 (Print) 2408-8684 (Online)

Journal of Bangladesh Agricultural University

Journal home page: http://baures.bau.edu.bd/jbau

Research Article

Effects of Municipal Solid Waste Landfill on Agricultural Land

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ARTICLE INFO

Article history
Received: 27 September 2024
Accepted: 22 June 2025
Published: 30 June 2025

Keywords
Solid waste,
Landfill,
Agricultural land,
Crop production

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OPEN ACCESS

ABSTRACT

The study was under taken to identify the effect of municipal solid waste landfill of Shambhuganj, Mymensingh, on agricultural land. Soil samples were collected from landfill, from the adjacent side of the landfill and from 20m, 40m and 60m away from the landfill. Collected samples were analyzed to determine Soil texture, pH, Electrical conductivity, Organic matter, Total nitrogen, C/N ratio and Exchangeable potassium. The results showed that the texture of the collected soil samples is mainly clay loam and soils were acidic in reaction (average pH is found 4.174). The Electrical conductivity ranged from 2.1 to 6.4 mS/cm. Organic matter, Total nitrogen, C/N ratio ranged from 4.52% to 6.81%, 0.44% to 0.20% and 7.56:1 to 14.4:1 respectively. Exchangeable potassium of the soil ranged from and 1369.87 ppm to 4052.66 ppm. Considering the investigated parameters, the land around the landfill site of Shambhuganj, Mymensingh, is not suitable for crop production. The different soil properties are way above the optimum level except the organic matter, which eventually make the land unsuitable for crop production.

Introduction

Waste may be discarded as worthless, defective, or of no use, but the Waste Framework Directive (EU, 2008) has inferred that waste is anything intended for recycling, recovery, reuse, or refinement by a process from that which produced the original resources. Municipal solid waste (MSW) is waste that is either collected by the municipality or disposed of in municipal waste facilities, it includes waste generated by residential, industrial, institutional, commercial, municipal, and construction/demolition sources (Hoornweg et al., 2012). Recently, the volume of garbage, particularly MSW, has been quickly increasing in many nations globally due to rising living standards or industrial and corporate expansion (Chen et al., 2019 and Krzykawska, 2019). This growing waste burden often results in the establishment of landfills near agricultural lands, raising serious concerns about the environmental and health impacts of landfill leachates on agricultural soil and crop productivity (Alamgir & Ahsan, 2007; Shakir et al., 2017).

Municipal solid waste management presents significant challenges, particularly in densely populated countries like Bangladesh, where rapid urbanization and population growth have led to an exponential increase in waste generation. Landfilling is one of the most common and widely used way for disposing of MSW at the end of its life (Stanczyk-Mazanek et al., 2019). MSW disposed of in landfills reacts and transforms chemically, physically, and biologically, releasing nutrients, elements, and gasses (Zornoza et al., 2016). One critical aspect to consider for a solid waste landfill is leachate, created when the wastes come into contact with water. Leachates contain both biodegradable and non-biodegradable organic molecules, humic substances, ammonia nitrogen (N), heavy metals (HMs), and chlorinated salts (Shen et al., 2018). Numerous researches have been conducted to address the composition of leachates and their impact on the environment, vegetation, and human health (Shu et al., 2018; Vaverková et al., 2018; Jain et al., 2005).

Cite This Article
Islam, R.. Rokonuzzaman, Rahman, M.S. and Sumon, M.H. 2025. Effects of Municipal Solid Waste Landfill on Agricultural Land. *Journal of Bangladesh Agricultural University*, 23(2): 141-147. https://doi.org/10.3329/jbau.v23i2.82581

In Bangladesh, proper landfill procedures are often not followed, leading to open dumping and potential unwanted spreading of leachate in the surrounding environment. This improper disposal method exacerbates the risk of contamination. Leachates from MSW landfills have diverse compositions, and iological testing is increasingly utilized to assess their toxicity (Zloch et al., 2018). When leachate enters agricultural land near the landfill, it alters soil properties such as pH, electrical conductivity (EC), organic matter content, total nitrogen, C/N ratio, and exchangeable potassium. These soil properties are crucial for land fertility, and any adverse changes can significantly impact agricultural productivity (Sharma et al., 2018). Additionally, leachate reaching surface water or groundwater sources can lead to contamination and pose serious health risks.

Previous research has primarily focused on the general environmental impacts of landfills, with limited attention given to their effects on agricultural land (Alamgir & Ahsan, 2007; Sharholy et al., 2008). For instance, Alamgir and Ahsan (2007) discussed broader environmental impacts of landfill leachates, while Sharholy et al. (2008) highlighted MSW management challenges in Indian cities, which share similar demographic and environmental conditions with Bangladesh. However, these studies did not explicitly evaluate how landfill contamination affects key soil parameters crucial for crop productivity. More targeted research on the agricultural impacts of landfill contamination is required, and it is critical to understand the interactions between waste management practices and agricultural sustainability.

In response to this research gap, this study aims to characterize the soils collected from areas at or near landfills in Bangladesh, focusing on key soil properties such as texture, pH, electrical conductivity, organic matter content, total nitrogen, C/N ratio, and exchangeable potassium. By characterizing these soil properties, we can gain insights into the extent of contamination and its potential effects on soil health and agricultural productivity.

Methodology

The tests of different properties of the collected soil samples were conducted in Soil Science Laboratory of the Department of Soil Science, Faculty of Agriculture, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh. A chronological description of the methodology used for this piece of research is briefly described below.

Study location

The study was conducted at Shambhuganj Municipal Solid Waste Landfill (24°45'07.7"N 90°26'00.6"E) in Mymensingh City Corporation (Fig. 1). Mymensingh City Corporation covers 91.315 square kilometers and had a population of 471,858 (Khan et al., 2018). Currently, Mymensingh produces approximately 150 tons of waste every day, of which the city authority collects 130-140 tons, accounting for over 90% of total waste, while 10-20 tons stay in various streets and drains throughout the city (Khan et al., 2018). It is expected that trash creation will double to 280 tons per day and 0.40 kg per person (LGED, 2017).

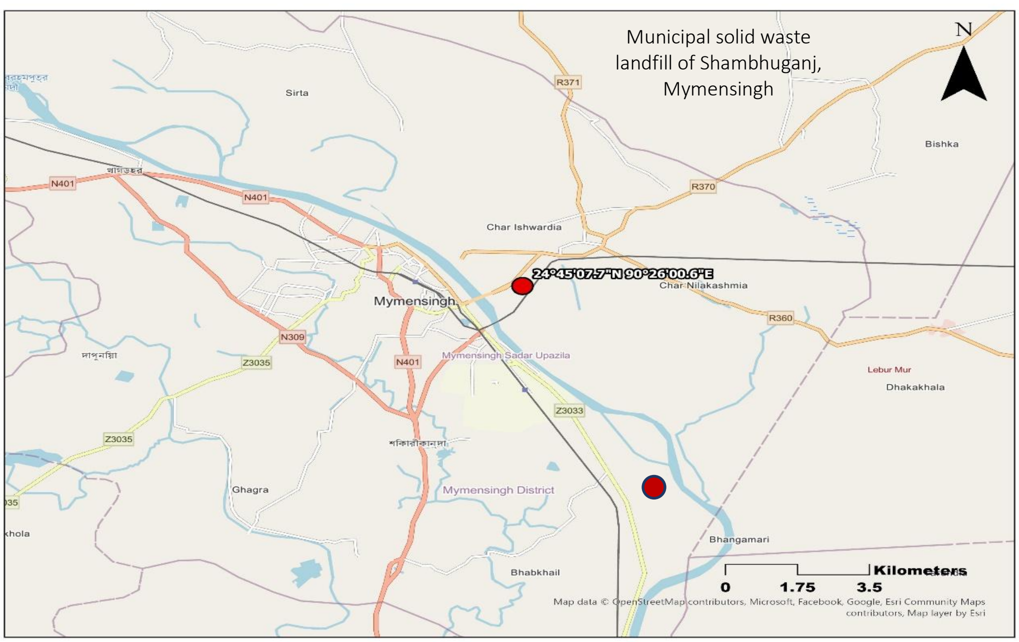

Figure 1. Study location of municipal solid waste landfill of Shambhuganj, Mymensingh

Soil sample collection

Soil sampling may be defined as the collection of soil from the field and it's processing for subsequent mechanical and chemical analysis. All the sample were collected from the top layer of the soil at the same day. Soil samples were collected from different place i.e. from the landfill site, from the immediate side of the landfill site and from a distance of 20m, 40m and 60m away from the landfill site.

Table 1. Soil sample collection location

Sample Code	Location
LS	Landfill site
ILS	Immediate side of landfill site
LS20	20m away from the landfill site
LS40	40m away from the landfill site
LS60	60m away from the landfill site

Soil sample preparation

For conducting the different laboratory test the samples were spread on brown paper for air drying and stones, brick pieces, roots of crop and other foreign materials were removed by hand. After the completion of the drying of the samples were then grind and pass them through a 2mm (10 mesh) sieve. Then the sieved soil was mixed to obtain a composite sample. Three replications were made from each sample for more accuracy. After that the soil sample were collected in label a plastic zipper.

Experimental methods

The experimental methods for analyzing soil samples involved several tests to determine key soil properties. All the test was done following slandered method. Soil texture was determined using the Hydrometer method(Lopez et al., 2021). Soil pH was measured with a glass electrode pH meter (Kumar et al., 2015), and electrical conductivity (EC) was assessed using a conductivity meter (Zhang & Wienhold, 2002). Organic matter content was analyzed using the wet oxidation method (Mingorance et al., 2007). Total nitrogen was determined by the micro semi-micro Kjeldahl method (Bremner, 2009), and the C/N ratio was calculated by dividing the organic carbon mass by total nitrogen. Exchangeable potassium was measured using the ammonium acetate extraction method (Shuman & Duncan, 1990). These tests collectively provide an in-depth analysis of soil quality and the effects of landfill leachates on agricultural land.

Results and Discussion

Soil texture

Soil texture, such as loam, sandy loam, or clay, describes the relative proportions of sand, silt, and clay particles that compose the soil's mineral content. Percentage of sand, silt and clay and the textural class of different samples are given below in the Table 2 and Table 3 respectively. All the sample except the one which is collected from the landfill site fall in the class of clay loam soil and the sample collected from the landfill site fall in sandy loam class.

Table 2. Percentage of sand, silt and clay of the soil sample

Sample Code	%Sand	%Silt	%Clay
LS	62.56	29.72	7.72
ILS	28.56	43.72	27.72
LS20	28.56	37.72	33.72
LS40	29.56	38.72	31.72
LS60	26.56	40.72	32.72

Table 3. Textural class of the different soil sample

Sample Code	Textural class
LS	Sandy loam
ILS	Clay loam
LS20	Clay loam
LS40	Clay loam
LS60	Clay loam

Loam, considered the ideal soil for plant growth, is a balanced blend of sand, clay, and silt (Weil and Brady, 2017). Commonly known as topsoil or black dirt by landscaping companies, loam typically consists of approximately 40% sand, 40% silt, and 20% clay. From the above table we can see that the samples contain high amount of clay. Clay soils are generally less suitable for agriculture due to their poor drainage, tendency to harden when dry, and restricted root penetration, which collectively reduce crop yields and thereby not suitable for agriculture (Hazelton and Murphy, 2016).

Soil pH

Soil pH, also known as soil reaction, indicates the acidity or alkalinity of the soil and is measured in pH units. It is defined as the negative logarithm of the hydrogen ion concentration. The pH scale ranges from 0 to 14, with 7 being neutral. The average pH values of various soil samples range from 3.12 to 5.38, as shown in Fig. 2, aligning with findings by Muñoz-Meléndez et al. (2000). The pH range of 6 to 7 is ideal for nutrient availability, microbial activity, and root function in most crops, though adaptations exist for acidophilic or calciphilic species. (Weil and Brady, 2017).

Clearly the pH is higher than the optimum and can be classified as strongly alkaline. Hence, on the basis of pH the land around the landfill site isn't suitable for crop production.

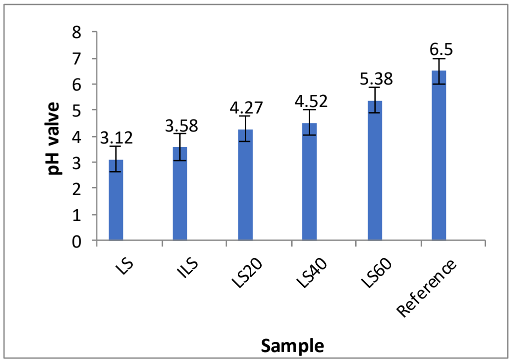

Figure 2. pH of soil samples

Electrical conductivity (EC)

Soil electrical conductivity (EC) measures the salt content in the soil, indicating soil salinity, which is a key indicator of soil health. Electrical conductivity (EC) plays a crucial role in agriculture by affecting crop yields, nutrient availability, soil microorganism activity, and overall crop suitability. Elevated EC levels, often caused by excessive salts, can disrupt plant growth by altering the soil-water balance, leading to reduced water uptake, nutrient imbalances, and increased stress on plants. Additionally, EC influences microbial activity, impacting soil respiration and greenhouse gas emissions (Shrivastava & Kumar, 2015). The EC values of various soil samples range from 2.1 to 6.4 mS/cm (Fig. 3), consistent with findings by Oberlin (2013).

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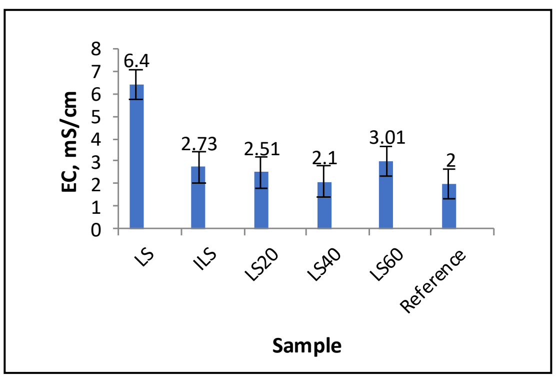

Figure 3. Electrical Conductivity of soil samples

EC values above 2 mS/cm can significantly impact young trees (Marosz and Nowak, 2008). The ideal EC reading for most plants is between 1.2-1.6 during the vegetative stage and 1.6-2.4 during flowering (Sonneveld & Voogt, 2009); however, these ranges can vary based on the specific plant species. The EC levels in the soil samples are considerably higher than the optimal range. The higher EC levels will impede nutrient absorption by raising the osmotic pressure of the nutrient solution, leading to nutrient wastage and increased nutrient runoff into the environment, which can cause environmental pollution.

Organic matter

Soil organic matter (SOM) is the organic fraction of soil, comprising three main components: fresh (small) plant residues and microorganisms, decomposing (active) organic matter, and stable organic matter (humus). Highly productive agricultural soils typically contain between 3% and 6% organic matter, which plays a crucial role in enhancing soil fertility, structure, and water-holding capacity (Weil and Brady, 2017).In the soil samples analyzed, organic matter content ranges from 4.52% in the sample taken 60 meters away from the landfill site to 6.81% in the sample collected directly from the landfill. A similar finding was reported by Mouhoun-Chouaki et al. (2019).

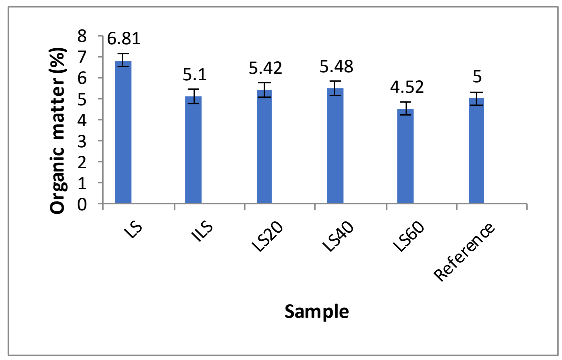

Figure 4. % Organic matter content in the soil samples

Increasing organic matter content enhances soil fertility by improving soil aggregation, which strengthens soil structure. A well-structured soil enhances permeability, allowing better water infiltration and increasing moisture retention, ultimately supporting healthier plant growth (Bronick & Lal, 2005). As shown in Fig. 4, the organic matter content in the collected soil samples is high, indicating favorable conditions for crop production.

Total Nitrogen (N)

Landfill soil has a high nitrogen content. Total nitrogen comprises nitrate (NO3), nitrite (NO2), organic nitrogen, and ammonia, all expressed as N. Nitrogen is essential for plant growth, food processing (metabolism), and chlorophyll production. A nitrogen deficiency can stunt plant growth, causing shorter stature and yellowing leaves, while excessive nitrogen can be detrimental, leading to leaf burn, shriveled foliage, and reduced flower or grain production (Xu et al., 2012). Moreover, high nitrogen levels can adversely affect groundwater and marine environments. In the analyzed soil samples, total nitrogen (N) content ranges from 0.44% to 0.20%. Similar findings were reported by Flower et al. (1981). The nitrogen levels in different soil samples are presented in Table 4 and Fig. 5.

Table 4. Total nitrogen

Sample Code	Total nitrogen in %	Total nitrogen in ppm
LS	0.44	4400
ILS	0.39	3900
LS20	0.31	3100
LS40	0.22	2200
LS60	0.20	2000

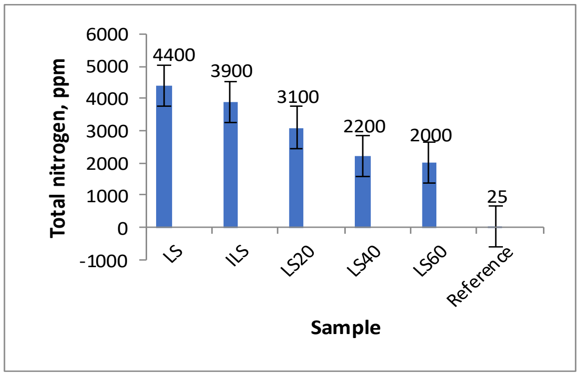

Figure 5. Total nitrogen in the soil samples

The optimal nitrogen levels vary depending on crop yield and soil conditions; however, for most field crops, 20 to 30 ppm is generally sufficient. Higher nitrogen levels may be necessary for achieving especially high yields or for specific vegetable crops. The nitrogen content in the analyzed soil samples exceeds the optimal range. This excess nitrogen can lead to an overproduction of biomass, such as stalks and leaves, while poorly supporting root development.

C/N ratio

The carbon to nitrogen (C/N) ratio of soil is defined as the ratio of the mass of carbon in the soil to the mass of nitrogen present in that soil. The C/N ratio of the collected soil samples are given below in the Table 5.

Table 5. C/N ratio of the soil sample

Sample Code	%Carbon (C)	%Nitrogen (N)	C/N ratio
LS	3.94	0.44	8.95:1
ILS	2.95	0.39	7.56:1
LS20	3.14	0.31	10.1:1
LS40	3.17	0.22	14.4:1
LS60	2.59	0.20	12.9:1

A proper balance of carbon and nitrogen in soil is essential for microorganisms. Soils with a carbon-to-nitrogen (C:N) ratio of 24:1 create an optimal environment for soil microbes, promoting the efficient release of essential nutrients like nitrogen, phosphorus, and zinc to crops. Maintaining this balance is vital for sustaining microbial health and overall soil fertility (Paul, 2016). However, the C/N ratios of the collected soil samples are significantly lower than this optimal level. Consequently, based on the C/N ratio, the land surrounding the landfill site is not suitable for agricultural crop production.

Exchangeable Potassium (K)

Potassium is a crucial essential nutrient for plant growth. As the most abundant inorganic cation, potassium (K) plays a vital role in promoting optimal plant development (White et al., 2010). It activates many essential enzymes involved in activities like protein synthesis, sugar transport, nitrogen and carbon metabolism, and photosynthesis. The exchangeable potassium levels in the soil samples ranged from 1369.87 ppm to 4052.66 ppm, as illustrated in Fig. 6.

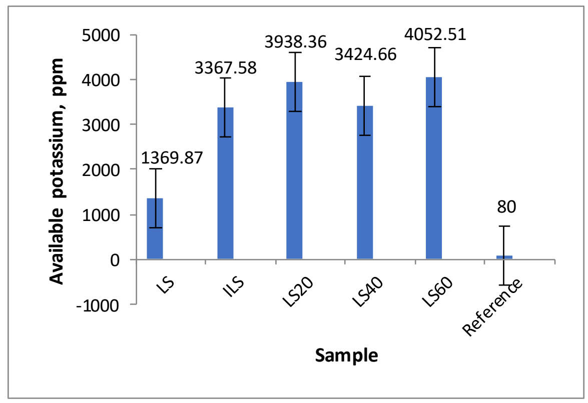

Figure 6. Exchangeable potassium in the soil samples

Potassium is essential for transporting water, minerals, and carbohydrates in plant tissues. It is also involved in enzyme activation, which influences the production of proteins, starch, and adenosine triphosphate (ATP). Healthy potassium levels in soil typically range from 40 to 80 ppm. One of the key hazards connected with high potassium is the possibility of nitrogen deficiency, which can limit plant growth and cause chlorosis, which is characterized by yellowing of the leaves that shows first on older growth lower down the stem. As shown in Fig. 6, the potassium levels in the soil samples significantly exceed the optimal range, and this excess potassium will likely hinder crop production.

Conclusion

This study assessed the impact of municipal solid waste landfills on agricultural land by analyzing soil properties around the Shambhuganj, Mymensingh landfill site. The results indicate that soil pH ranged from 3.12 to 5.38, electrical conductivity from 2.1 to 6.4 mS/cm, organic matter content from 4.52% to 6.81%, total nitrogen from 0.44% to 0.20%, C/N ratio from 7.56:1 to 14.4:1, and exchangeable potassium from 1369.87 ppm to 4052.66 ppm. These findings suggest that, despite the presence of organic matter, the land surrounding the landfill is largely unsuitable for crop production due to unfavorable pH, high electrical conductivity, and imbalanced nutrient composition. This study bridges a critical research gap by providing a focused evaluation of how landfill leachates alter soil properties, with direct implications for agricultural productivity. The findings emphasize the urgent need for better leachate management strategies to prevent contamination, particularly during the rainy season when leachate migration is intensified. To mitigate the adverse effects of landfill leachates on agricultural land, future studies should incorporate trace element analysis, including heavy metals such as copper (Cu), lead (Pb), and cadmium (Cd), to further assess long-term soil contamination risks. Additionally, implementing engineered landfill liners, leachate treatment systems, and sustainable waste disposal practices is crucial to reducing the environmental footprint of MSW landfills. A more integrated approach to waste management, including recycling and composting initiatives, could significantly reduce landfill dependence and protect agricultural resources

Authors contribution

Rafiqul Islam and **Rokonuzzaman:** Conceptualization, sample collection, performed the laboratory test and writing original draft; **Dr. Mahmud Hossain Sumon:** Guidance and data evaluation; **Md. Siddikur Rahman:** Supervision. All authors read the article and approved the final version to be published.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors would like to thanks the reviewers for their thoughtful and constructive comments and efforts towards improving this manuscript. This work was self-funded by the authors.

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