Pol. J. Environ. Stud. Vol. XX, No. X (XXXX), 1-9
DOI: *10.15244/pjoes/191612* ONLINE PUBLICATION DATE:

Original Research

Physicochemical Properties of Soil around the MSW Dumpsite in North East Coast – A Sustainable Waste Management Practice

Hemalatha Vegi[1], V.D.N Kumar Abbaraju[1]*, B.S.A Andrews[2], N.V.S Venugopal[2], Mahadi Danjuma Sani[3]

[1]Department of Environmental Sciences, GSS, GITAM Deemed to be University, Visakhapatnam, Andhra Pradesh – INDIA – 530045
[2]Department of Chemistry, GSS, GITAM Deemed to be University, Visakhapatnam, Andhra Pradesh – INDIA – 530045
[3]Department of Environmental Science, Federal University Dutse, Jigawa State, Nigeria-720223

Received: 11 March 2024
Accepted: 24 July 2024

Abstract

This present work reveals the multifaceted challenges arising from unregulated municipal solid waste (MSW) dumping in the North East Coast, Visakhapatnam, India. It investigates the environmental and public health impacts, emphasizing the intricate connection between MSW management, soil quality, and broader environmental consequences. The available Ca^{2+} value is about 4.7. For this work, a comparison of contaminated soil samples with the ideal range of micronutrients required for plants is measured. A standard calibration curve for this analysis by atomic absorption spectroscopy (AAS) using sodium ion (λ = 589 nm) is also measured. The proportion of soil in the selected communities at the dumpsites of the south coastal zone of INDIA represents the standard error of means measured. Unmanaged MSW disposal not only degrades the visual landscape but also accumulates heavy metals, posing risks to soil and groundwater quality. The parameters are assessed by using XRD, SEM, and AAS. The results obtained revealed that the soil near the dumpsite lacks essential nutrients for plant growth and contains low organic carbon levels. Rectifying these deficiencies is crucial for agricultural purposes. Moreover, excessive soluble SO_4^{2-} and Cl^- and other mineral levels can hinder plant development. This underscores the urgency of responsible waste management practices in developing nations.

Keywords: Heavy metals, soil contamination, waste management, public health, sustainable development

*e-mail: vabbaraj@gitam.edu

Introduction

The management of municipal solid waste (MSW) in Nigeria, particularly through open dumping or burning, is common [1]. This study in Obollo-Afor and Nsukka, Southeastern Nigeria, assessed its impact on soil properties and heavy metal distribution. Significant differences ($P<0.05$) in chemical and physical properties of soil were observed, influenced by MSW. Heavy metal concentrations were higher in MSW dumpsites but within WHO limits for agricultural soils. The study examined soil physiochemical properties near the power-line dumpsite in BojiBoji Owa, Delta State, Nigeria. [2] Significant differences were found between dumpsite and control site values. pH ranged from 6.22±0.06 to 7.97±0.04 in dumpsite soils, compared to 39.8±0.08 in the control site. Higher pH correlated with increased Cation Exchange Capacity (CEC), ranging from 4.73±0.30 to 10.28±0.46 mEq/100 g. Electrical conductivity (Ec) varied from 692±4.50 to 918±4.03 μScm^{-1} across dumpsites. In developing countries like Ghana, open dumpsites and landfills cause severe environmental pollution. [3] This study examined contaminants in dumpsite waste and soil, focusing on physiochemical properties and heavy metal distribution. Significant differences were found in concentrations of various elements. Urban dumpsites showed high levels of cadmium (41.7 mg/kg) and iron (4355 mg/kg). The fine particles were heavily polluted with cadmium. High potential ecological risks were identified. The findings highlight the urgent need for proper waste management and technology for dumpsite reclamation. Discharging untreated municipal solid wastes (MSWs) [4] onto land is widespread in developing countries, causing harmful effects on humans and the environment. This study evaluated the impact of solid waste discharge on soil quality within the Ain-El-Hammam municipality landfill (Algeria). Results showed that MSW increased soil organic matter (4.53%) and heavy metal concentrations (Cu, Zn, Cd, Pb, Ni, and Cr), indicating significant pollution levels. Improper waste disposal can pollute soil, affecting groundwater and vegetation [5]. This study in Achan, Srinagar, analyzed soil quality around a dumping site. Results showed lower bulk density at the dumpsite with increasing distance. Soil moisture, pH, EC, OC, organic matter, and CEC were higher at the dumpsite, declining with distance. Cations, micronutrients, and heavy metals followed this trend. Most parameters varied significantly among sampling sites, except for soil pH and nitrogen. Soil properties at municipal solid waste dumpsites in Bayelsa State, Nigeria, were characterized [6]. Samples from three dumpsites (Opolo, Mechanic Village, Kpansia) and natural soil (control) were examined. Results showed significantly higher pH, nutrients, and electrical conductivity at dumpsites compared to natural soil (control) ($P < 0.05$). Exchangeable acidity was lower at the dumpsites, while heavy metal contents were higher, albeit within permissible levels by WHO. Overall, soil conditions at the dumpsites support agricultural productivity. A survey at the Regional Agricultural Research Station, Anakapalle, Andhra Pradesh [7] evaluated the influence of municipal solid waste on soil properties in Visakhapatnam. Analyzing samples from seven dump yards, the study found a positive impact on soil fertility, with increased nitrogen, phosphorus, and potassium due to municipal waste. Urban solid waste management is a global concern [8], affecting human health and the environment. Characterizing stabilized waste, this study suggests potential uses as earth fill and secondary raw material (SRM) for soil subgrade. In the Kaduna metropolis, representative solid waste samples were collected from three dumpsites, showing varying heavy metal concentrations [9]. Soil quality at municipal solid waste dumpsites in Hurghada [10] was assessed, revealing elevated heavy metal levels in dumpsite soils compared to drainage pattern samples. Indiscriminate municipal waste dumping [11] in Nigerian cities severely pollutes soil. In Omuooke-Ekiti, SW Nigeria, heavy metal concentrations around a dumpsite exceeded thresholds, indicating significant soil pollution. Poor waste management [12] in India contaminates soil and groundwater, as observed in Silchar, NE India, with high levels of trace elements and unfit groundwater for consumption near dumping sites. The study assesses soil quality at three municipal waste dumpsites in Allahabad, Uttar Pradesh [13], revealing neutral to alkaline pH with high water holding capacity and moisture content. Elevated levels of Cr, Cu, Fe, Ni, Pb, and Zn were found, with significant correlations between physico-chemical properties and heavy metal concentrations. Improper waste management [14] in India poses risks from waste accumulation. Analyzing Mumbai's Mulund dumpsite's fine fraction (<4 mm), aged 1-10 years, heavy metal levels exceed limits despite meeting compost standards for pH and electrical conductivity. Groundwater contamination from municipal waste dumping poses health risks [15], with widespread contamination observed. Parameters like EC, TDS, and Total Hardness exceed WHO limits at 38% of sites. Although some parameters are within limits at all sites, heavy metals like iron and zinc surpass WHO limits at various percentages of sites. Regular monitoring and management are essential to protecting water resources.

Municipal solid waste (MSW) management has historically caused substantial issues in several places, including Visakhapatnam. Unfortunately, the repercussions of mismanaged MSW dumping have resulted in a slew of environmental issues in Visakhapatnam and other similar cities. The impact of open MSW dumping extends beyond the ugly appearance of landfill sites. Heavy metals and other contaminants poison the soil near these dumpsites, which can have far-reaching implications. These toxic substances can persist and bioaccumulate in the ecosystem, causing a range of problems. This study, therefore, emerges in response to these multifaceted challenges. It seeks to investigate the physicochemical properties of the MSW dumpsite in Visakhapatnam, specifically focusing on parameters such as pH, electrical conductivity, soil texture, moisture content, organic carbon, organic matter, available nitrogen, available phosphorus, and available potassium. The analysis also aims to analyze the presence and concentration of heavy metals (Ni, Cd, Cr, and Pb, etc.,) in the MSW samples and their impact on soil. The current research challenge focuses on the negative environmental and health implications of mismanaged MSW dumping practices. The prevalent "out of sight, out of mind" approach to MSW disposal, motivated by the economic problems of safe landfills, has historically resulted in a slew of issues. Because toxic compounds can persist and bioaccumulate in the ecosystem, heavy metal poisoning poses considerable threats not just to the environment but also to human health. This analysis aims to shed light on these crucial concerns, emphasizing the significance of responsible waste management, data gathering, and region-specific solutions to alleviate the continued environmental and health risks connected with MSW dumping.

Materials and Method

Visakhapatnam, colloquially known as Vizag, is a rapidly developing metropolitan area located in the northeastern coastal region of Andhra Pradesh, as depicted in Figs. 3.1 and 3.2. Encompassing an area of approximately 545 square kilometers, the city is positioned between 17°15' and 18°32' Northern latitude and 18°54' and 83°30' Eastern longitude. Geographically, Visakhapatnam is bordered to the north by the state of Orissa and Vizianagaram District, to the south by Kakinada District now, to the west by Orissa State, and to the east by the Bay of Bengal. The Gajuwaka area MSW dumpsite was chosen for this research. This work aims to address these important challenges by emphasizing the importance of responsible waste management, data gathering, and the necessity for location-specific solutions to mitigate the ongoing environmental and health risks connected with MSW dumping. The study area is represented in Fig. 1.

Experimental

Samples of both MSW and soil were collected. To guarantee comprehensive coverage, fresh MSW samples were collected from the dumpsite, totaling 100.00 kg of representative samples over five days. Soil samples were collected from the dumpsite at a depth of 10-15 cm using soil augers. The collected MSW samples were processed by air-drying, grinding, and sieving through a 2 mm sieve to prepare them for analysis. For soil samples, they were shade-dried to a constant weight and sieved through a 2 mm stainless steel sieve, and clods were broken down with a mortar and pestle to ensure homogeneity. The analysis of physicochemical properties included determining pH and Electrical Conductivity (EC) using digital meters (Hanna Digital meter), soil texture classification based on particle size (sand, silt, clay), calculation of soil moisture content using the gravimetric method (following weighing and drying the soil sample to determine the moisture content), estimation of organic carbon and organic matter content through titrimetric methods, measurement of available nitrogen using distillation with alkaline potassium permanganate solution, determination of available phosphorus through Bray's method No. 1, and evaluation of available potassium extracted with 1 M Ammonium acetate using flame photometry.

Fig. 1. Study area.

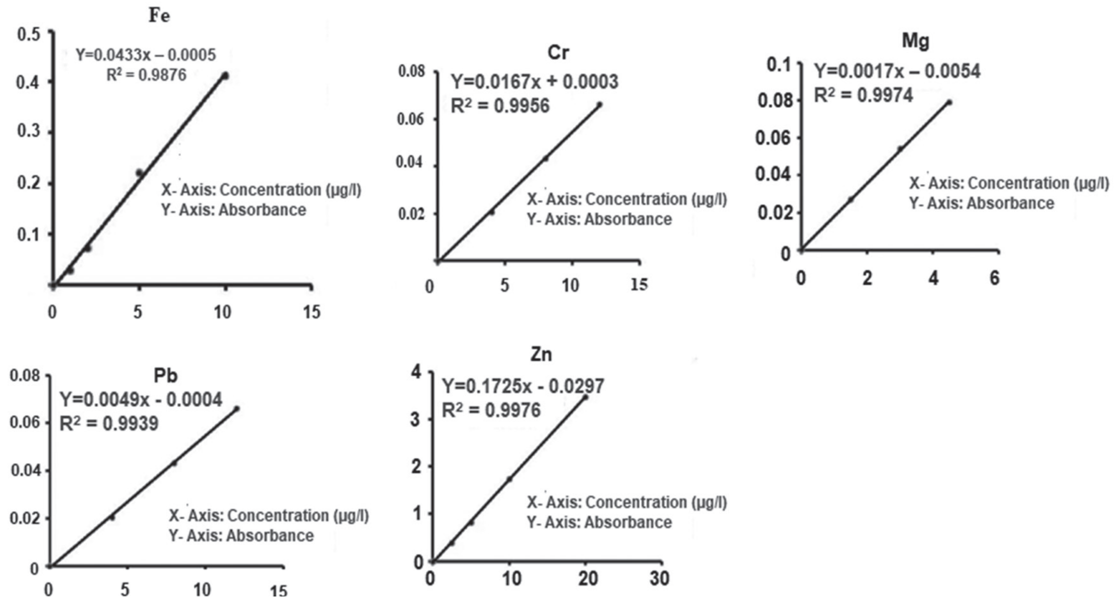

Fig. 2. Some of the standard calibration curves for analysis by atomic absorption spectroscopy using sodium ion (λ = 589 nm).

Fig. 3. Sample collection in various locations of the dumpsite.

For the assessment of heavy metal accumulation, MSW samples were prepared by digestion using aqua regia to analyze the levels of heavy metals (Ni, Cd, Cr, and Pb), and pre-treated soil samples were similarly prepared using acid-digestion. The final extracts were then analyzed for heavy metal content using an Atomic Absorption Spectrophotometer (AAS) for both MSW and soil samples. The obtained standard calibration curves for different metals are represented in Fig. 2.

These comprehensive methods and techniques provided valuable insights into the physicochemical properties and heavy metal accumulation in the studied MSW dumpsite. Fig. 3 represents the sample collection in various locations of the dumpsite.

Results and Discussion

There are significant levels of heavy metals and other soil quality parameters in the MSW, according to the data in Tables 1 and 4. A higher mean value of 135 µ mohrs was recorded for EC during the analysis. The moisture content of (12%), pH (6.2), available calcium as Ca (4.7%), available nitrogen (1.5%), available phosphorous and soluble chlorides (1.3%), soluble sulfate as SO_4^{-2} (1.2%), available magnesium as Mg (1.14%), a small amount of organic carbon (0.3%), and organic matter (0.2%) were observed. As revealed in Tables 1 and 4, solid wastes deposited at the landfill have significant physicochemical and metallic burdens that are high enough to contaminate the soil there as a result of leachate from the waste heaps migrating into the soil strata and eventually penetrating the groundwater, as presented in Table 1.

Table 1. Overall average physico chemical parameters in the MSW at the dumpsite.

S/N	Test parameters	Units	Average value at Gajuwaka District
1	Available calcium	Wt%	4.7
2	Moisture	Wt%	12
3	Available nitrogen	Wt%	1.5
4	Available phosphorus	Wt%	1.3
5	Electrical Conductivity	µ Mohr's	135
6	Organic carbon	Wt%	0.3
7	Organic matter	Wt%	0.2
8	pH		6.2
9	Soluble sulfate	Wt%	1.2
10	Available magnesium Mg	Wt%	1.14
11	Soluble chlorides	Wt%	1.3

Pearson's Correlation Coefficient

In the present analysis, the correlation coefficient for the soil physico-chemical properties and heavy metal concentrations was calculated. The positive and significant correlations were found between Ca with moisture (.776*), N (.764*), OM (.734*), SO4-2 (.706*), Mg (.766*), and NaCl (.803**), likewise moisture with N (.999**), OM (.944**), SO4-2 (.837**), Mg (.948**) and NaCl (.941**), likewise N with (.938**), SO_4^{-2} (.829**), Mg (.949**) and NaCl (.933**), likewise P with EC (.750*) and pH (.669*), likewise EC with pH (.822**), likewise OM with SO_4^{-2} (.910**), Mg (.870**), and NaCl (.974**), likewise SO_4^{-2} with Mg (.777**) and NaCl (.926**) and Mg with NaCl (.834**) of water sample. In other words, a positive correlation indicates that changes in one variable have an equal impact on changes in another. It also indicates that a relationship between two variables tends to evolve in the same direction. The proportions of soil in the selected communities are represented in Fig. 4.

None of the variables in the table showed negative or non-significant correlations, even though the other variables showed non-significant correlations. With the very lowest levels, every other metric exhibited a negative correlation or significance. Thus, this work concluded that, in addition to the careless disposal of municipal solid waste, several other activities, such as industrial processes, air deposition, etc., are also responsible for the heavy metal pollution in the dumpsite. The results are represented in Table 2 and Table 3.

The comparison of various test parameters for a contaminated soil sample with the ideal range of micronutrients required for plant growth reveals important insights. The soil contains 4.7% of available calcium, slightly below the ideal range of 5%, indicating a need for a slight increase in calcium content. Moisture content stands at 12%, falling short of the optimal 20%, suggesting the soil is relatively dry. Available nitrogen is a significant concern, with only 1.5% compared to the ideal range of 20-40%, necessitating nitrogen fertilizer

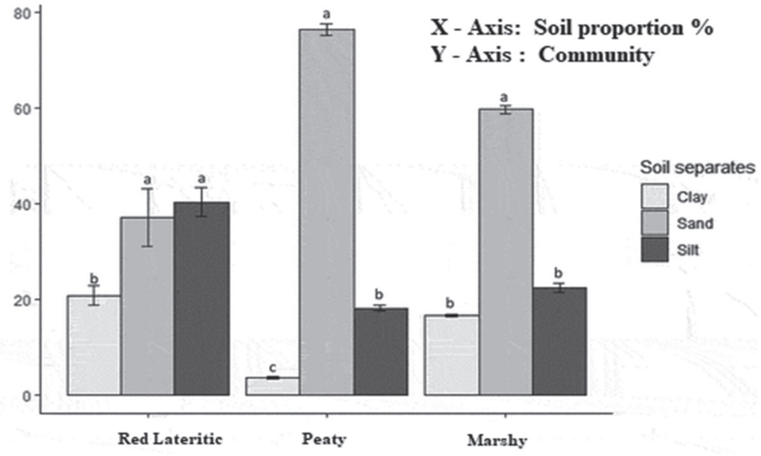

Fig. 4. Proportion of soil in the selected communities in the dumpsites of the south coastal zone of INDIA and the standard error of means.

Table 2. Correlation matrix for soil physico-chemical properties.

	Ca	Moisture	N	P	EC	OC	OM	PH	SO4-2	Mg	NaCl
Ca	1	.776*	.764*	0.151	-0.084	0.319	.734*	0.334	.706*	.766*	.803**
Moisture		1	.999**	0.182	0.124	0.081	.944**	0.391	.837**	.948**	.941**
N			1	0.199	0.144	0.08	.938**	0.397	.829**	.949**	.933**
P				1	.750*	0.446	-0.133	.669*	-0.129	0.303	-0.094
EC					1	-0.258	-0.158	.822**	-0.341	0.085	-0.121
OC						1	0.004	-0.14	0.256	0.317	0.007
OM							1	0.16	.910**	.870**	.974**
PH								1	0.009	0.317	0.232
SO4-2									1	.777*	.926**
Mg										1	.834**
NaCl											1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

for improved plant growth. Available phosphorus, at 1.3%, is also below the desired range of 25-50 ppm, highlighting a deficiency that should be addressed. The electrical conductivity is within an acceptable range, suggesting reasonable salinity levels. Organic carbon (0.3%) and organic matter (0.2%) fall short of the ideal ranges (0.5-7.5% and 5-10%, respectively), calling for organic material enrichment to enhance soil quality. A pH of 6.2 is suitable for most plants. However, the high levels of soluble sulfate (1.2%) and soluble chlorides (1.3%) require attention, as they may have adverse effects on plant growth.

Table 3. Comparison of a contaminated soil sample with the ideal range of micronutrients required for plants.

S/N	Test parameters	Units	Contaminated range	Ideal range
1	Available calcium	Wt%	4.7	5
2	Moisture	Wt%	12	20
3	Available nitrogen	Wt%	1.5	20-40 %
4	Available phosphorus	Wt%	1.3	25-50 ppm
5	Electrical Conductivity	µ Mohr's	135	110-570
6	Organic carbon	Wt%	0.3	0.5-7.5
7	Organic matter	Wt%	0.2	5-10%
8	pH		6.2	5.5-7.5
9	Soluble sulfate	Wt%	1.2	0.3-0.5
10	Available magnesium Mg	Wt%	1.14	0.05-0.5
11	Soluble chlorides	Wt%	1.3	0.01-0.5

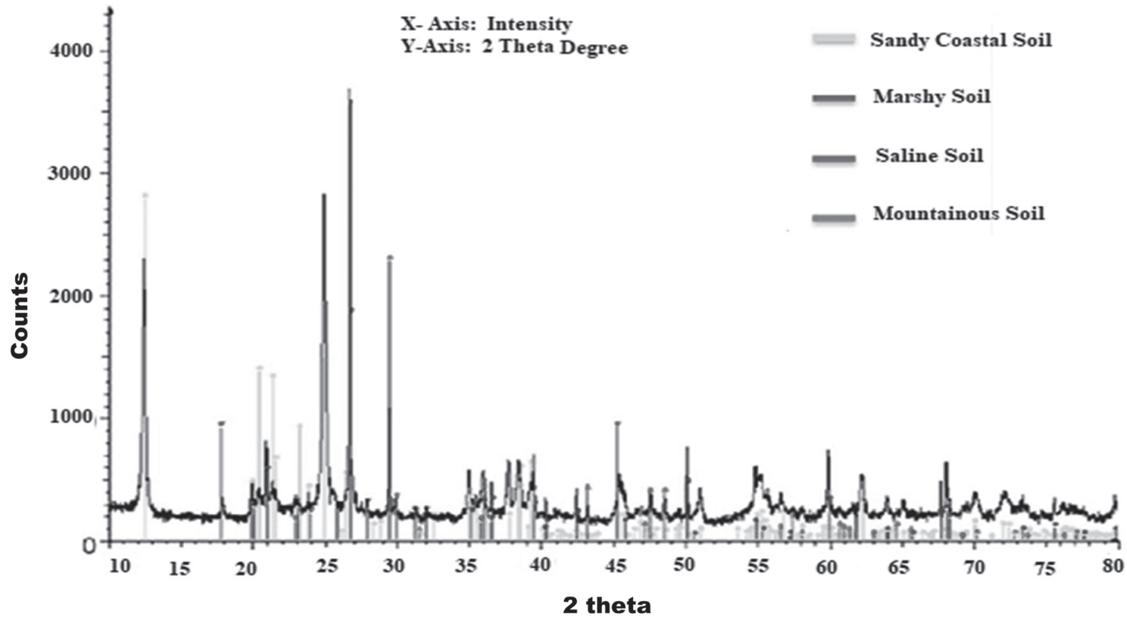

Fig. 5. Untreated clay soil XRD patterns.

Untreated clay soil XRD patterns are represented in Fig. 5.

In summary, the soil sample would benefit from nitrogen and phosphorus fertilization, organic matter addition, and measures to reduce excessive sulfate and chloride levels to optimize it for successful plant cultivation. Tailoring these interventions to the specific plant species and agricultural goals is essential. The results are tabulated in Table 4.

The data reported in this analysis undertaken at the Visakhapatnam MSW dumpsite shows numerous significant discoveries and their ramifications. The presence of heavy metals in MSW samples is one of the important results, raising concerns about environmental and human health. SEM images for stabilized soil samples are represented in Fig. 6.

This shows that the landfill has amassed a significant metallic burden, which can eventually lead to soil and groundwater contamination as garbage heap leachate migrates into the soil. Heavy metal contamination in MSW is a severe issue that must be handled to avoid long-term ecological and health concerns. Numerous defects are revealed by the analysis of the physicochemical properties of the soil close to

Table 4. Distribution of concentrations of heavy metals in MSW in Visakhapatnam.

MSW containing Heavy Metals	Concentration in mg/Kg	Mean Concentration as mg/Kg	Standard Deviation
Cr	779.03 - 10199.60	4978.294	2699.036
Pb	589.37-13616.20	5220.651	34183.509
Fe	67.69-319.10	156.209	59.351
Cu	69.66-333.60	171.583	70.496
Ni	57.96-187.10	109.178	38.709
Cd	27.03-133.50	72.736	27.399
Al	15.81-129.40	50.559	33.477
Co	6.12 -111.00	26.752	21.875
As	2.25 -102.50	12.620	25.381
Sb	0.17-3.00	1.388	0.688
Hg	0.14-97.30	7.719	24.668
Mn	0.03 -105.30	7.164	27.262
Zn	9.39-97.50	35.266	26.722

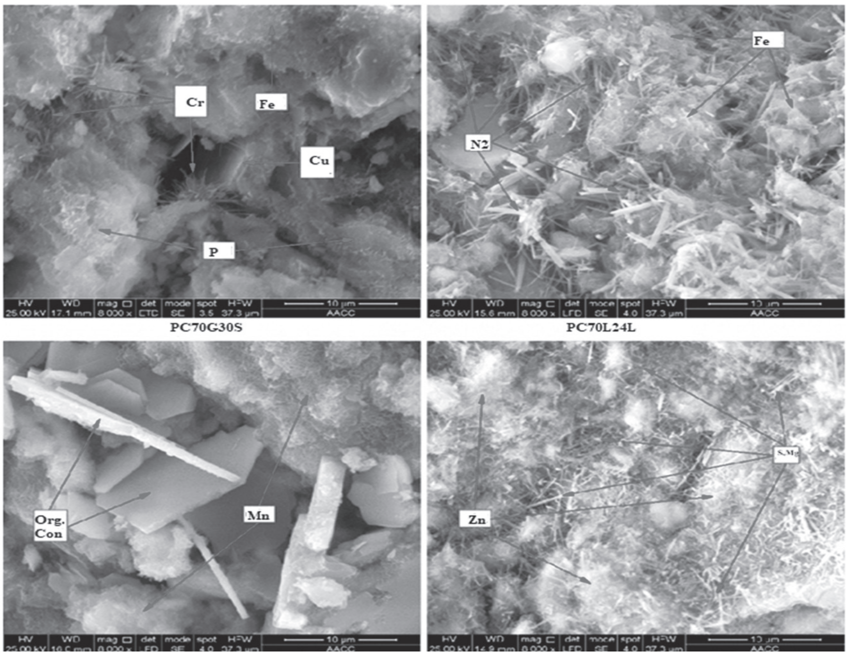

Fig. 6. Scanning electron microscope (SEM) images of the stabilized soil samples.

the dump site. Important nutrients that are necessary for plant growth, such as readily available nitrogen and phosphorus, are absent from the soil. In addition, the soil contains insufficient levels of organic matter and carbon, two elements that are critical to microbial activity and soil fertility. Moreover, the soil's comparatively low moisture content of 12% denotes dry conditions, which could hinder plant growth even more. This analysis suggests methods to treat nutritional deficiencies and enhance the soil for maximum plant production, such as adding fertilizers high in phosphate and nitrogen. It is also critical to enrich the soil with organic materials to increase its organic carbon and organic matter content, which will improve soil structure, water retention, and microbial activity. Furthermore, steps should be taken to prevent high levels of soluble sulfate and soluble chlorides, which can harm plant growth. The consequences of these findings go beyond the scope of the current work. They highlight the critical importance of proper waste management practices and precise data collection. Unmanaged MSW dumping has been demonstrated to result in heavy metal deposition in soil and groundwater, posing serious environmental and health risks. Contaminated soil can harm vegetation development, and groundwater pollution is dangerous to human health. These findings highlight the significance of specialized, region-specific solutions to the complex problems connected with MSW dumping. This sheds light on the intricate interaction between garbage management, soil quality, and environmental impact. It emphasizes the importance of tackling these issues, particularly in developing countries, through responsible waste management practices, reliable data gathering, and site-specific solutions to reduce environmental and health concerns.

Conclusions

This research carried out at the Visakhapatnam MSW dumpsite provides new information about the health and environmental hazards connected to improper MSW disposal practices. This present work underscores the importance of conscientious waste management, gathering data, and devising site-specific remedies to address these persistent issues, especially in developing countries. The MSW sample's notable concentration of heavy metals highlights the urgent need for efficient waste management techniques. Because they have the potential to contaminate soil and groundwater, accumulated heavy metals pose serious threats to the environment and public health. As a result, the contamination has extensive effects on the physicochemical characteristics of the soil, the growth of vegetation, and public health. Low amounts of organic carbon and organic matter, as well as deficits in important nutrients like available nitrogen and available phosphorus, are highlighted by the evaluation of the soil's characteristics close to the dump site. Addressing these deficiencies is crucial to optimizing the soil for successful plant cultivation. Additionally, efforts should be made to reduce high levels of soluble sulfate and soluble chlorides, which can negatively impact plant growth. Overall, the research findings underscore the need for tailored, region-specific waste management solutions. The challenges associated with unmanaged MSW dumping go beyond the unsightly appearance of landfill sites; they extend to contamination of soil and groundwater, posing ecological and public health risks. Responsible waste management practices, accurate data collection, and location-specific strategies are imperative to mitigate these multifaceted challenges. This not only sheds light on the complex interplay between waste management, soil quality, and environmental impact but also serves as a reminder of the importance of addressing these issues in the broader context of developing nations. The research findings underscore the significance of responsible waste management to ensure the well-being of both the environment and the communities that are impacted by unmanaged MSW dumping.

Acknowledgments

There was no funding received from any agency. Sincere thanks to the management of GITAM University for providing the necessary facilities to carry out this research.

Conflict of Interest

The authors declare that they have no conflicts of interest among the authors.

References

1. AZUKA C.C., EZEM C. Influence of Municipal Solid Waste Dumpsite on Soil. Journal of Bioresource Management, **10** (3), 104**, 2023**.
2. ULAKPA R.O.E., ULAKPA W.C., EYANKWARE M.O. Quantitative analysis of physical and chemical attribute of soil around power-line dumpsite at Boji-Boji Owa, Delta State, Nigeria World News of Natural Sciences, **35**, 118, **2021**.
3. GYABAAH D., AWUAH E., ANTWI-AGYEI P., KUFFOUR R.A. Physicochemical properties and heavy metals distribution of waste fine particles and soil around urban and peri-urban dumpsites. Environmental Challenges, **13**, 100785, **2023.**
4. MOUHOUN-CHOUAKI S., DERRIDJ A., TAZDAIT D., SALAH-TAZDAIT R. A Study of the Impact of Municipal Solid Waste on Some Soil Physicochemical Properties: The Case of the Landfill of Ain-El-Hammam Municipality, Algeria Applied and environmental soil science, (5), 1, **2019**.
5. PANDIT B.A. Municipal Solid Waste (MSW) and its Impact on Soil Properties in and around the Achan Dump Site in Srinagar, Jammu & Kashmir. International Journal for Research in Applied Science & Engineering Technology (IJRASET), **11** (12), 239, **2023**.
6. OSIM S.E., MBOSOWO E.M., EZE U.P., UDO J.I., LUCKY S.A. Characterization of Physical and Chemical Properties of Soil from Three Municipal Solid waste Dumpsites in Bayelsa State, Nigeria. International Journal of Scientific and Research Publications, **10** (10), 401, **2020**.
7. SANJANA D., RAMALAKSHMI C.H.S., LATHA M., MURTHY K.V.R. Effect of municipal solid waste on soil properties in Visakhapatnam city. The Pharma Innovation Journal, **11** (10), 2185, **2022**.
8. SALUJA S., GAUR A., AHMAD K. Physico-chemical characterization of stabilized MSW of an Okhla landfill. Materials Today: Proceedings, **44** (6), 4287, **2021**.
9. WUNZANI D.K., DAUDA M.S., WYASU G., DAVID D.A.A. Assessments of physicochemical properties and heavy metals content in soils from selected solid waste dumpsites in kaduna metropolis, kaduna state, Nigeria. Science World Journal, **15** (1), 76, **2020**.
10. MOHSEN A.E.S., DABA E., WAHAB M.A.E. Heavy Metal Contamination and Physicochemical Properties of Soils in Municipal Solid Waste Dumpsite, Hurghada, Red Sea, Egypt. Egyptian Journal of Aquatic Biology & Fisheries, **24** (7), 913**, 2020.**
11. AFOLAGBOYE L.O., ABAYOMI A.O.J.O., TALABI A.O. Evaluation of soil contamination status around a municipal waste dumpsite using contamination indices, soil-quality guidelines, and multivariate statistical analysis**.** SN Applied Sciences, 2, 1864, **2020.**
12. CHOUDHURY M., JYETHI D.S., DUTTA J., PURKAYASTHA S.P., DEB D., DAS R., ROY G., SEN T., BHATTACHARYYA K.G. Investigation of groundwater and soil quality near to a municipal waste disposal site in Silchar, Assam, India. International of energy and water resources, **6** (1), 37, **2022**.
13. TRIPATHI A., MISRA D.R. A study of physico-chemical properties and heavy metals in contaminated soils of municipal waste dumpsites at Allahabad, India. International journal of environmental sciences, **2** (4), 2024, **2012**.
14. SINGH A., CHANDEL M.K. Physicochemical and FTIR spectroscopic analysis of fine fraction from a municipal solid waste dumpsite for potential reclamation of materials. Waste Management and Research, **39** (2), 374, **2021**.
15. KUMARI S., BHAWNA. Physicochemical properties of Groundwater around Municipal waste disposal sites: a Review IOSR Journal of Engineering (IOSRJEN), **10** (8), 12, **2020**.