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Impacts of Unsystematic Solid Waste Dumping on Soil Properties and Climate Change

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Abstract

Purpose: Open-air dumping is a significant problem in Gilgit City, with limited research analyzing waste generation and its physicochemical impact on the soil. This study aimed to evaluate the effects of open dumping on soil properties and compare them with a controlled site. **Research Design, data, and Methodology**: Using ANOVA, the study found significant differences in electrical conductivity (EC), soil organic matter (SOM), soil organic carbon (SOC), sand, silt, and clay between the two sites, except for pH. Pearson correlation revealed that pH negatively correlated with EC, sand, and silt, but positively with SOM, SOC, and clay. The control site's mean EC was 6.06 mS/m, whereas the dumping site recorded 8.5 mS/m. EC is inversely related to SOM, SOC, silt, and clay, but directly to sand. SOC and SOM values varied significantly, with notable differences in soil texture components like clay and silt. **Results:** The research highlights the detrimental effects of unsystematic waste dumping on soil health and its contribution to greenhouse gas emissions, particularly methane, which exacerbates climate change. **Conclusion:** The study concluded that waste deposition and decomposition significantly impact EC, SOM, SOC, and soil texture, though pH remains unchanged. The unsystematic dumping of solid waste contributes to climate change through methane production, a potent greenhouse gas. To mitigate these impacts, the study recommends regular monitoring, waste prevention, recycling strategies, and continuous training for stakeholders to achieve sustainable development.

Keywords : Open Dumping, Waste Generation, SOM, SOC, Soil texture, Clay, Sand, ANOVA, Temperature, Sustainable Development.

JEL Classification Code : C15,C83,C91,Q53,Q54

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1. Introduction

The unsystematic dumping of solid waste has emerged as a critical environmental issue, posing significant threats to both soil health and global climate stability. Solid waste management is a crucial aspect of environmental stewardship, involving the collection, transportation, processing, recycling, and disposal of waste materials. However, when waste is dumped without proper management, it leads to severe environmental degradation. Soil quality is a crucial factor in the sustainability of agriculture and is described as "the fitness of a particular type of soil to fulfill its duties, in a natural and managed ecosystem, to sustain organisms' productivity, regulate air and water quality, and support human health and habitat," among other functions (Karlen et al., 1997, 2003, 2004). The concept of soil quality encompasses soil fertility, potential productivity, pollutant levels and their impacts, resource sustainability, and environmental quality. A common definition of soil quality is the degree of a soil's suitability for a particular use, highlighting its significance for both agricultural and natural ecosystems (Kádár, 1992; Várallyay, 1992, 1994, 2005; Márton, 2005; Márton et al., 2007). Soil, as part of the world's land resources, is "limited, fragile, and nonrenewable" (Lal, R. 1995). It is estimated that approximately 22% (3.26 billion hectares) of the world's total land area is suitable for agriculture, with only around 3% (450 million hectares) having a high potential for agricultural production. The status of soil in agriculture and the environment is a matter of worldwide concern, because soil is in abundant but limited supply, and some soil components cannot be replenished within a human time frame (Howard, 1993; FAO, 1997). Maintaining soil quality is also crucial for protecting human health, as poorly managed and contaminated soils can negatively affect air, groundwater, and surface water, and expose people to harmful substances in residential areas (Kádár, 1992; Várallyay, 2005; Cook & Hendershot, 1996; Németh, 1996; Malcolm, 2000; Márton et al., 2007). Contaminants in soil, such as heavy metals, toxic substances, excessive nutrients, volatile and non-volatile organic materials, explosives, radioactive isotopes, and inhalable fibers, pose significant risks (Sheppard et al., 1992; Cook and Hendershot, 1996). Unfortunately, anthropogenic activities like the careless disposal of solid waste are deteriorating soil qualities. Heavy metal contamination can have detrimental effects on humans, animals, and soil productivity (Smith et al., 1996). Understanding how land use affects soil properties is vital for sustainable food production (Fesha et al., 2002). Unsystematic waste dumping can lead to soil contamination through the leaching of hazardous substances, such as heavy metals and organic pollutants, altering the soil's chemical properties and negatively impacting plant growth and soil microorganisms (Alkassasbeh et al., 2009).

In developing countries, open dumpsites are common due to low budgets for waste disposal and a lack of trained manpower. For example, open dumping of municipal solid waste (MSW) is a prevalent practice in Pakistan, posing serious threats to groundwater resources and soil and air. Heavy metal contamination in soil can adversely affect human health, animals, and soil productivity (Smith et al., 1996). Over the years, heavy metals have significantly damaged soil quality and fertility due to increased pollution from industrial, agricultural, and municipal sources (Adriano, 1986). Metals cause physiological disorders in soils, as absorption through root systems retards plant growth and deprives plants of vigor (Moustakas et al., 1994). Waste carries various metals that transfer to plants in different ways (Voutsa et al., 1996). Depending on the contaminants' tendencies, they may end up in soil water or leach into groundwater, affecting soil chemistry and impacting organisms and plants reliant on the soil for nutrition (Shaylor et al., 2009). In many developing countries in Asia, high population growth and economic development have led to widespread open dumping of solid waste. This issue is particularly pressing in regions like Gilgit-Baltistan in Pakistan, where human activities, extreme weather events, and a fragile mountain ecosystem exacerbate natural resource degradation (Begum et al., 2019). Gilgit City, the fastest-growing urban area in the province, produces approximately 87.6 tons of waste daily, with 72.86 tons collected by the Gilgit Waste Management Company, representing about 83% of the total waste generated. However, 16% of the waste remains uncollected, and this figure is projected to rise due to population growth and other factors (GWMC spokesman, 2022).

The connection between unsystematic solid waste dumping and climate change is primarily through the emission of greenhouse gases (GHGs). Organic waste in landfills undergoes anaerobic decomposition, producing significant amounts of methane (CH_4), a potent greenhouse gas with a global warming potential much higher than carbon dioxide (CO_2) (Bogner et al., 2007). The open dumping of waste significantly contributes to climate change through the generation of landfill gas, particularly methane, which has a potent greenhouse effect (Rahman, 2010; Sudarman, 2010; Chaudhary, 2014). This issue is further exacerbated by dump site fires, which release high levels of pollutants, including methane, into the atmosphere (Rim-Rukeh, 2014). Converting open dumps into landfill sites can mitigate these emissions and even provide a source of green energy (Chaudhary, 2014). Therefore, effective waste management strategies are crucial in reducing the environmental impact of open dumping. Unattended solid waste leads to various environmental nuisances, including aesthetic degradation, breeding grounds for vermin, production of offensive odors, methane release into the environment, and resource waste (International Resource Group, 2009). Gilgit-Baltistan has become increasingly urbanized, generating significant waste from residential, educational, and other sectors. In Gilgit, large volumes of waste are regularly collected and dumped in Chilmish Das, near a hospital and technical college, without any treatment. The increasing dumping rate contributes significantly to environmental pollution, affecting both human and animal lives and the environment. Improper waste disposal without treatment releases greenhouse gases, contributing to climate change, and attracts insects and pathogens that spread diseases.

This study aims to assess the effects of open dumping on soil physical and chemical properties and the variation between dumped and control sites, as well as the impact on climate change. The goal is to inform policymakers, government agencies, and waste management companies about the importance of proper waste disposal to protect environmental and human health.

1.1. Problem Statement

Solid waste management is a critical and prevalent issue in mountainous regions like Gilgit, where it significantly impacts the natural environment and biodiversity. The improper disposal of solid waste leads to pollution of land, water, soil, and air. Soil, which serves numerous essential functions in our daily lives, has seen a decline in quality due to human activities, particularly the disposal of hazardous waste. The chemicals and non-biodegradable materials in waste alter the physical and chemical properties of the soil, while the emission of greenhouse gases such as methane contributes to global warming, leading to glacier melt. This, in turn, triggers heavy rains and flash floods, which can seep sewage into the ground and push garbage into rivers, posing significant health risks to downstream populations. In addition to the local environmental impacts, the unsystematic dumping of solid waste contributes significantly to global climate change. Organic waste in open dumps undergoes anaerobic decomposition, producing methane, a potent greenhouse gas with a global warming potential much higher than carbon dioxide. These emissions exacerbate global warming, which can lead to more extreme weather events, sea level rise, and disrupted ecosystems worldwide. Therefore, addressing the issue of open dumping is not only crucial for local environmental health but also for mitigating broader climate change impacts. Municipalities and community groups often lack access to vital information on improving waste management systems and utilizing waste economically. Consequently, this study aims to assess the impact of open dumping on soil physicochemical parameters. Despite recognizing these challenges, there are no effective or consistent practices in place to mitigate the excess solid waste problem. Hazardous waste collection and open burning of untreated waste along riverbeds and roads remain common practices, leading to severe human health issues and environmental degradation.

1.2. Contribution of the Study

This study makes a significant contribution to the field of waste management and environmental science by providing a comprehensive analysis of the impact of open-air waste dumping on soil properties and climate change in Gilgit. By employing detailed physicochemical assessments and statistical analyses, it offers new insights into how waste deposition affects soil quality, particularly in terms of electrical conductivity, soil organic matter, and texture. The findings highlight the critical role of waste management practices in influencing greenhouse gas emissions, particularly methane, which has profound implications for climate change. This research not only fills a notable gap in the current literature for the Gilgit region but also informs practical and policy measures aimed at improving waste management strategies. The study underscores the urgent need for enhanced waste management practices, including better monitoring and recycling initiatives, to mitigate environmental and climatic impacts. Furthermore, it provides a foundation for future research into more sustainable waste management solutions and their broader implications for environmental health and climate stability.

2. Literature Review

2.1. Impact of Unsystematic Dumping on Soil Properties

Jilani studied municipal solid dumping and its impact on soil quality in Karachi. The findings demonstrated that the amount of biodegradable organic waste, primarily food waste (70%), in Karachi's residential areas' municipal solid waste (MSW) was significantly greater. Due to the waste disposal, the concentrations of heavy metals, organic carbon, volatile solids, pH, EC, and TDS in the soil have all increased when compared to the control site. The overall mean metal concentrations in the soil at the dumpsite were in the order of Zn>Cr>Pb>Cu>Ni>Cd. The analysis of the metal concentrations revealed that they were all below the permeable limits, except for lead. However, when compared to control sites, the trend suggested that the concentration of pollutants was probably going to grow. According to the study's findings, MSW dumping has modified the physio-chemical properties of the soil in addition to changing its color and texture. (Jilani, 2020) In a study, an effort was made to determine the effects of municipal solid waste (MSW) on a few physicochemical characteristics of landfill soil used as a model in the Ain-El-Hammam municipality. To accomplish this, a variety of soil physicochemical factors were considered, including granulometry, electrical conductivity, pH, organic matter content, and heavy metal concentration. Results showed that the MSW had an impact on the soil's physicochemical features by raising the organic matter content of the soil (4.53%) and increasing the heavy metal content (Cu, Zn, Cd, Pb, Ni, and Cr), which is a clear indication of the amount of contamination they are producing (Mouhoun-Chouaki, 2019). According to (Beyene and Banerjee 2011) the constant application of dumping of all types of solid waste on land led to the accumulation of metals in receiving soils and the release of concentrated leachate into the environment, which then entered the food chain in the form of meat and milk. It is anticipated that over time it could pose a threat to food safety. (Gbola et al., 2017) conclude his study and said uncontrolled disposal of these solid wastes into the environment has greatly harmed our ecosystem by releasing pollutants such as heavy metals, which can be dangerous to humans if consumed directly or indirectly, and plants, which depend on the nutrients from the soil for their growth and development. Another study Inappropriate dumping in sites raises questions, Unlimited and unchecked emissions of various compounds into soil prevent soil bacteria from developing and, as a result, reduce their number and enzymatic activity, disrupting the homeostasis of the soil environment (Boruta et al., 2016). soil PH, conductivity, and enzymic activity have a more specific correlation towards soil biota, surprisingly a small impact on chemically and structurally organic matter connected to soil minerals has been accounted (Tonon, (2010).). soil productivity at a large scale could be disturbed due to open-air dumping (Anikwe, 2002). The metal concentrations over the threshold levels have significantly impacted soil downstream and near the dump site. One of the main elements determining the mobility and solubility of metals in the soil environment is the soil's pH, which ranges from acidic to alkaline. In such pH levels, the soil can hold additional heavy metal burdens. These heavy metals have a propensity to bio-magnify and cause long-term detrimental effects on ecosystems in terms of biochemical and toxicological effects on people and other components of our planet (Parth et al., 2011). According to Steffan et al. (2018) Whether those effects are good or bad, direct or indirect, the soil has a significant impact on human health. The nutrients in our food supply and drugs like antibiotics come mostly from the soil. Health issues, however, might result from nutrient imbalances and the presence of human pathogens in the soil biological community. There are also many places where different metals or chemical compounds are found in soil in dangerous quantities due to either anthropogenic activity or natural conditions. Unplanned management of biomedical waste has been related to risks for those who are either directly or indirectly involved in this field of work. It has become difficult to protect the quality of the soil, water, and air due to biomedical waste (Manzoor & Sharma, 2019).

Similarly, management practices are also concerned with preserving the environment before it degrades, practices like environmentalism, conservation strategies, and other environmental management exercises, the Municipal Solid Waste (MSW) is highly neglected performing management practices in low-income countries (Murtaza & Rahman, 2000) and is more anxious to complication of MSW in its management and interventions (Shimura et al., 2001; Sharholy et al., 2000) thus allocating very low annual budget for the fiscal year, reflecting more danger to environment and human well-being (Bartone, 1999). Suggested readings of environmental management describe Waste management planning as a subset of environmental management combining the evaluation of Biophysical and Socio-economic impacts of disposable resources in a particular manner (Morris & Holthausen, 1994; Chuck, 1999; Agarwal et al., 2005). Lowest GDP and developing countries such as Somalia, Sudan, Nigeria, India (Das et al., 2002; Sharholy et al., 2000) and Pakistan (Adila et al., 2008; Adila & Nawaz, in press) the waste collection system is poorly managed and estimated collection in not more than 60% of total generated waste. The rest of the 40% Waste lies in our Geophysical environment, streets, open plots, drains, and sewer lines. The Management structure comprises primary, secondary, and open dumping of Municipal Solid waste. According to the study (JICA, 2005) 55000 tons/day is being generated in Pakistan having a population size of about 160 million where 35% of dwellers are urban settled. Only the Lahore city is generating around 5000 tons of solid waste per day (KOICA – World Bank, 2007). Proper research exercises, lack of institutional framework, financial planning, and shortage of skilled labor are also big challenges to optimize the current solid waste management framework in Pakistan

(KOICA – World Bank, 2007).

2.2. Contribution of Solid Waste Dumping to Greenhouse Gas Emissions and Climate Change

(EI-Fadel & Massoud 2000) studied climate change research highlights the significant role of methane emissions from municipal solid waste landfills, a major anthropogenic source. This study reviews methane formation mechanisms, estimation methods, and emission comparisons, using Lebanon as a case study. It also discusses mitigation measures tailored to economic and technological conditions, emphasizing the importance of effective waste management in reducing greenhouse gas emissions. (Rim-Rukeh 2014) Municipal solid waste open dump site operations in Nigeria present significant health risks due to frequent fires, which release harmful pollutants such as suspended particulate matter, carbon dioxide, and carbon monoxide. These emissions pose a particular threat to dump site workers and the surrounding community. Improved waste management practices and effective emission control measures are urgently needed to mitigate these health risks. Another study also evaluates greenhouse gas (GHG) emissions from municipal solid waste (MSW) management, highlighting that over 50% of waste in developing countries is improperly managed, contributing significantly to global GHG emissions. It underscores the need for sustainable waste management practices, including waste segregation, recycling, and the use of natural gas-based vehicles, to reduce emissions. Gichamo and Gökçekuş (2019) study reviews the relationship between solid waste and climate change, highlighting that solid waste contributes approximately 5% of global greenhouse gas emissions. It discusses how climate change exacerbates waste management challenges, such as increased household waste from flooding and heightened odor and dust from heat waves. The study emphasizes the need for integrated solid waste management practices, including waste prevention, reuse, recycling, and local treatment plants, to mitigate these impacts. In the context of Gilgit Baltistan, it has become an urban area as a result of immigration and growth, a significant amount of waste is produced here by the residential, educational, and other sectors. In Gilgit, a large volume of waste is regularly collected from homes, schools, and other workplaces, and it is dumped in Chilmis Das close to a hospital and technical college without any treatment. Environmental pollution, such as soil contamination, has a significant impact on both human and animal lives as well as the environment and is caused by the damping rate, which is increasing day by day. Due to the release of greenhouse gases, improper dumping of solid waste without any treatment has become a significant contributor to climate change. Organic waste decomposition releases greenhouse gases, which in turn attract various insects and pathogens and serve as a vector to spread diseases like malaria and fever. Dumping of waste produces leachate, which causes soil and groundwater contamination (Isidori et al., 2003). Therefore, the present study was conducted to assess the effect of open dumping on soil physical and chemical properties and the variation of properties between dumped and control sites and also to show its contribution to greenhouse gases. The goal of this study is to inform policymakers, government agencies, and WMC about the proper disposal of waste.

3. Research Methods and Materials

3.1. Description of the Study Area

This study was conducted at the Chilmish Dass dumping site, located in Gilgit Baltistan, Pakistan, next to Kund Dass. The geographical coordinates of the study area are latitude 35°58’37.67” N and longitude 74°19’26.47” E. The study area is surrounded by mountains, with the Hunza River flowing through it on its route to the Gilgit River. The route to Naltar passes through Chilmish Dass, and numerous roadside activities, including crushing plants, are situated on the other side of the road. Significant landmarks include a medical center and a boys' polytechnical college, both located to the right of the dumping site. This location was chosen due to its representative nature of the region's waste management challenges and its proximity to sensitive environmental and educational sites.

3.2. Map of the study area

The map of the study area and GPS coordinates of the location of the Chilmish Dass dumping site are shown in Figure 1.

Figure 1: Map of the study area and sampling location

3.3. Aims and Objectives

The objectives of this study are as follows.

1) To assess the effect of open dumping on soil physical and chemical parameters.
2) To identify variations in soil properties of solid waste dumping sites or control sites.
3) To evaluate the impact of open dumping on greenhouse gas emissions and its contribution to climate change.

3.4. Data Analysis

3.4.1. Laboratory Analysis

Soil samples were air-dried and manually sieved through a 2mm sieve and some of soil physical and chemical properties were determined. EC was measured by (An Electrical conductivity meter) from the standard procedure given in the US Handbook 60 (Richards, 1954) Soil pH was measured using a pH probe with the glass-calomel electrode and a 1:1 soil: water ratio (Mclean, 1982).

Soil texture was measured using the soil hydrometer method (Gee & Bauder, 1986). Soil organic matter and Soil organic carbon have been determined by dry combustion methods.

3.4.2. Soil Analysis

For physicochemical estimation, all soil samples were homogenized, air-dried, ground, and sieved using a 2mm mesh and stored in standard polythene bags. The treated soil samples were analyzed for pH, electrical conductivity, total dissolved solids, soil texture, SOC, and SOM using standard procedures described by (Rayment & Higginson 1992; Vesilind et al., 2003; Jilani 2007). Soil samples were conducted in the month of June 2022. Using a hand auger, random soil samples were taken from 0 to 3 cm in depth from the topsoil horizon. The control soil (site B) samples have highly moist and agricultural soil, it was taken in order to compare the effects and variation along both sites dumping of solid waste in Dumped site(A) and controlled site (B). A total of 24 soil samples including 12 from the dumping site and 12 from the control site were collected and analyzed using the standard method.

3.4.3. Statistical Analysis

Analysis of Variance (ANOVA) was used to determine the variation in soil physical and chemical parameters across dumped and controlled sites. Pearson Correlation analysis was performed to explore the relationships between various soil physico-chemical properties.

Table 1: ANOVA-F value with respect to dumped and control site

pH	EC (mS/m)	SOM%	SOC%	SAND%	SILT%	CLAY%
4.42 ^{ns}	11.3**	22.1***	22.3***	7.7**	5.75*	5.29*

Note: p<0.05* p<0.01** p<0.0001*** (shows significant) "ns"non-significant

Table 2: Mean and standard deviation of soil properties in dumped and control sites

SITES	pH	EC (mS/m)	SOM (%)	SOC (%)	SAND (%)	SILT (%)	CLAY (%)
DUMPED SITE	8.3±0.42	8.5±3.0	4.4±2.0	2.5±1.2	61.5±7.7	34.0±8.3	4.3±1.9
CONTROL SITE	7.8±0.43	6.06±4.3	0.4±0.1	0.2±0.1	77.3±1.1	20.2±1.1	2.3±0.81

Table 3: Correlation between soil parameters under different sites

	pH	EC (mS/m)	SOM (%)	SOC (%)	SAND (%)	SILT (%)	CLAY (%)
pH	1						
EC (%)	−0.6*	1					
SOM (%)	0.3	−0.5*	1				
SOC (%)	0.3	−0.5*	1.0**	1			
SAND (%)	−0.3	0.1	−0.7**	−0.7**	1		
SILT (%)	−0.3	−0.07	0.7**	0.7**	−0.9**	1	
CLAY (%)	0.3	−0.4	0.2	0.2	−0.3	0.2	1

4. Results and Discussion

4.1. Soil physical and chemical parameters at dumped and control site

The analysis of variance (ANOVA) was used to determine the impact of the dumping of solid waste on soil physical and chemical properties. The result of ANOVA showed that EC($p<0.01$) SOM($p<0.001$) SOC ($p<0.001$) sand ($p<0.01$) Silt ($p<0.05$) and clay ($p<0.05$) were significantly varying between both sites except pH ($p<0.05$) not significant (Table 1). The Analysis of Variance (ANOVA-F) showed significant results between the sample means when comparing the means of pH, EC, SOM, SOC, SAND, SILT, and CLAY. In the observation between the sample means the pH didn't show any significance towards sample means, resulting in different pH means. Whereas Silt and clay showed comparatively identical mean values.

4.1.1. pH and Electrical Conductivity

Physico-chemical characteristics of soils at both control and MSW disposal sites were compared using simple statistical plots. In general, soil composition, cation exchange processes, and hydrolysis reactions associated with the various organic and inorganic soil components as well as the CO2 concentration in the soil gaseous and liquid phase determine soil pH values, with pH values below 7 indicating (acidic) soil and above 7 indicating basic (alkaline) soil (Thomas and Hargrove, 1984). In our study, the soil at the mean value of the dumped site slightly increases from 7.8 (control) to 8.3 (maximum) (Table 2) (figure 2). The result of ANOVA shows that soil pH did not significantly vary between dumped and control sites. A variety of components are present in the solid waste in varying amounts. Due to the addition of MSW, the soil becomes contaminated with various nutrients and heavy metals.

The increase in soil pH is caused by the alkaline composition of trash. According to the study (Goswani & Sharma, 2008), the presence of CO_3, HCO_3, Na, K, and other alkaline elements in MSW at various concentrations is what causes the alkalinity. The pH value of compost should be between 5.5 and 8.5 to enable its safe use for growing food crops. Generally, it has been observed that pH has an unwavering association with the chemical qualities of soil and that plants are given access to more nutrients at pH values of 6.5 to 7.5 (Whalen, 2000; Praveena & Rao, 2016). (Giasquini et al., 1898) The availability of elements in the soil is significantly influenced by the pH of the soil. (Marschner, 1996). The Pearson correlation (Table 3) showed that pH has a significant negative correlation with EC, sand, and silt and a positive relation with SOM, SOC, and clay.

4.1.2. Electrical Conductivity

A significant difference in the mean value of EC was observed in the soil of both areas. It was found to be high at the control site while it was significantly different and found low at disposal sites. The mean value of EC at the control site was recorded as 6.06 mS/m while at dumped sites 8.5 mS/m respectively (Table 2 and Figure 3).

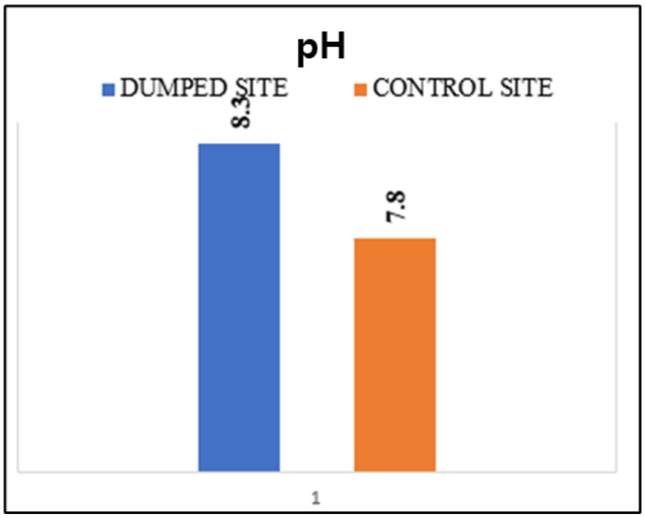

Figure 2: Mean value of soil pH

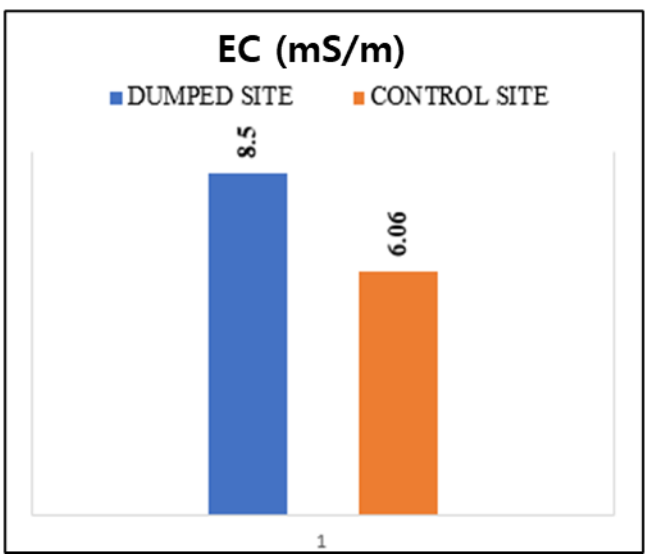

Figure 3: Mean value of soil EC

The hazards due to solid waste are most often encountered because of the high total salt and sodium content which can be studied by conductivity measurement. Conductivity values less than 0.5milli S/m are perfectly safe and it doesn't have a negative effect on plant growth. High EC can be toxic to plants and prevent them from obtaining water from soil according to a study by (Goswami & Sarma. 2008). The outcome of EC is primarily influenced by several environmental conditions, including climate, geology, local biota, and anthropogenic activities that alter soil characteristics. A pH between 7.3 and 8.5 indicates the presence of $CaCO_3$, and a saturated extract with large concentrations of neutral soluble salts will have a high electrical conductivity (EC >4 dS/m). A pH above 8.5 indicates the presence of significant amounts of exchangeable CO_3, and the electrical conductivity is typically low (EC 4 dS/m) (Narshimha et al., 2013). Our findings indicate that EC has a significant inverse relation with SOM, SOC, silt, and clay and has a direct relation with sand. (Table 3).

4.1.3. Organic matter content

The level of organic carbon is one of the most crucial soil features, and its absence may influence other soil properties. The soil's average SOC and SOM values have changed dramatically. It was observed to be high at the dump site and low at the control site. At the dump site, the mean values for SOM and SOC are (4.2) and (2.5), respectively, while at the control site, they are (0.4) and (0.2) (Table 2) (Figure 4). The main contributors to soil organic matter content include biodegradable waste, kitchen garbage, yard waste, falling leaves, and mostly open burning of waste. Organic matter is a crucial component of soil and environmental quality because it is a significant source and sink of essential plants and microbial nutrients and has a significant impact on physical, chemical, and biological processes. (King et al., 2020).

Organic waste can be composted to provide plant nutrients and can be applied as soil fertilizer. Vermicompost contains organic matter and organic carbon, which are the soil organisms' primary source of energy and can serve as plant nutrients when they are released in an assimilable form during microbial decomposition (Brady, 1996). The analysis of variance indicated that a significant difference in the mean values of SOM ($p<0.001$) and SOC ($p<0.001$) was observed in the soils of both areas. The results of the correlation identified that SOM and SOC both have a direct relation with each other, and both have a positive relation with clay and silt and have negative relation with sand (Table 3). The study of (King et al., 2019) clearly shows that the organic matter that has been absorbed into the soil can have an impact on the soil's strength, porosity, aggregation, and bulk density as well as the content and transmission of water, air, and heat.

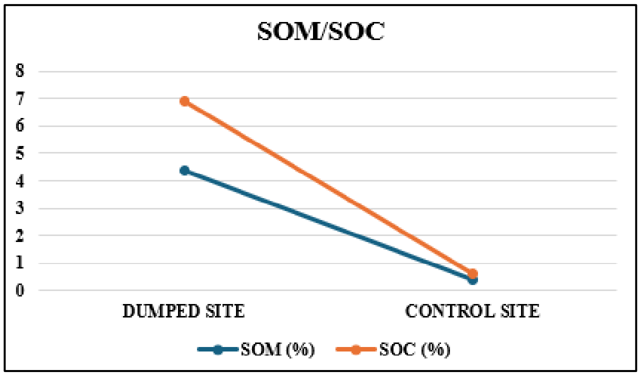

Figure 4: Mean values of SOC/SOM

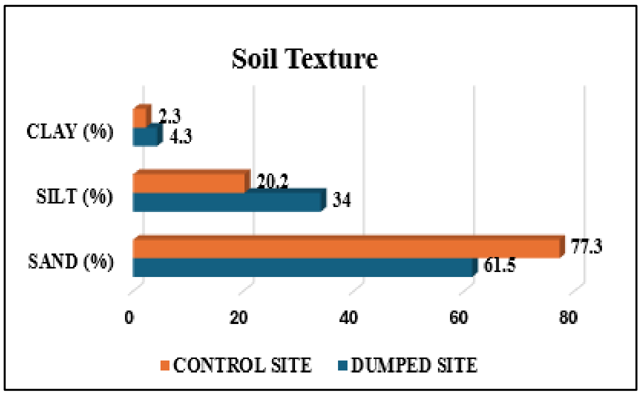

Figure 5: Mean values of soil texture (sand, silt and clay)

4.1.4. Soil Texture

The soil's texture reveals the relative number of different-sized particles, including sand, silt, and clay. The amount of water and air that soil can store, the efficiency with which it may be handled, and the rate at which water can enter and travel through the soil are all influenced by texture. By using the soil hydrometer method, soil texture will be measured. (Gee & Bauder 1986). The largest soil particle, sand, is readily apparent. When wet, it does not become slick or sticky and is grittier than most materials. The diameter of sand particles ranges from 2 to 0.05 millimeters. Silt is a term for medium-sized soil particles. Silt has a talcum or flour-like texture. When wet, it has a moderate water retention capacity and a slightly sticky texture. Silt particles range in size from 0.05 to 0.002 millimeters. Clay refers to the tiniest dirt particles. Only an extremely strong microscope can reveal most clay particles individually. When wet, clay feels slick; when dry, it feels unyielding. Compared to sand and silt, clay is more chemically active. The diameter of clay particles is smaller than 0.002 millimeters. (Salley et al., 2018).

However, the ANOVA analysis reveals significant differences in clay (p0.05), silt (p0.01), and temperature between the dumping location and the control site. The average value of sand was higher in the control site (77.3%) than the dump site (61.5%), the average value of silt was higher in the dump site (34.0%) than the control site (20.2%), and the average value of clay was lower at the control site (2.3%) than the dump site (4.3%), indicating that the unsystematic dumping of MSW is to blame (Figure 5) (Table 2). Sand proportion is significantly more impacted than silt and clay percentages. Clay and sand have a strongly negative relationship, while sand and silt have a favorable relationship (Table 3).

4.2. Relationship between Waste and Climate Change

A literature review confirms that there is a relationship between waste and climate, with waste management practices significantly contributing to greenhouse gas emissions.

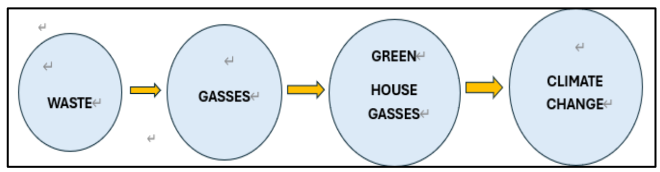

Figure 6: Relationship between waste and climate change

A comprehensive literature review confirms the significant relationship between waste management practices and climate change. Municipal solid waste (MSW) disposal, particularly through open dumping, substantially impacts greenhouse gas (GHG) emissions, contributing notably to the release of carbon dioxide (CO_2) and methane (CH_4) (Rafiq et al., 2018; Ngwabie et al., 2019). Quantitative studies have measured emissions from open dumpsites, with CH_4 emissions ranging from 96.80 to 213.44 mg m^{-2} min^{-1} and CO_2 emissions ranging from 224.78 to 1103.82 mg m^{-2} min^{-1}(Ngwabie et al., 2019. These emissions vary due to the heterogeneity of waste, stages of decomposition, and prevailing environmental conditions. For example, open dumps can emit up to 1000 kg CO_2-eq. $tonne^{-1}$, while conventional landfills equipped with energy recovery systems emit significantly less, at 60-300 kg CO_2-eq. $tonne^{-1}$(Manfredi et al., 2009).

To mitigate these GHG emissions, alternative waste disposal methods have been explored. Aerobic composting has shown promise in controlling emissions and reducing costs (Yedla & Sindhu, 2016). Additionally, utilizing landfill gas for electricity generation can significantly offset emissions, potentially reducing the net GHG impact to -70 to 30 kg CO2-eq. tonne−1(Manfredi et al., 2009). Despite these advancements, waste management remains a significant industry contributing to climate change, with every waste management process generating greenhouse gases both directly (via method-related emissions) and indirectly (through energy consumption) (UNEP, 2010).

Greenhouse gases significantly impact the ecological environment and climate change, largely due to their high carbon dioxide emission rates (Kardoğan et al., 2022). Numerous scientific studies have demonstrated that waste management procedures release greenhouse gases, including nitrogen dioxide (N2O), carbon dioxide (CO2), and methane (CH4) (Kristanto & Koven, 2019; Paes et al., 2020; Branschel & Posch, 2013; Ho et al., 2020; Lu et al., 2015; EPA, 2023a; Isaksson et al., 2020). The peak amount of CO2 in the atmosphere globally in 2019 coincided with an increase in all greenhouse gas emissions (Olivier & Peters, 2020). Organic waste consists of various materials, and when this waste is transferred to storage areas, microorganisms begin to decompose the carbon in the organic materials. Under anaerobic conditions, microorganisms produce methane, leading to the emission of methane, carbon dioxide, and other gases (UNEP, 2010). These gases trap heat in the atmosphere, contributing to the rise in global average temperatures, a phenomenon known as global warming (National Geographic, 2022).

In addition to climate change, improper waste management practices increase the risk of explosions and fires due to methane emissions from biodegradable waste (Agaçayak, 2019). These practices include unlawful waste storage, improper garbage processing, inadequate waste recycling, and unsuitable waste disposal, all of which elevate GHG emissions (UNDP, 2021). If greenhouse gas emissions continue to rise, global climate change will accelerate, leading to sea-level rise, melting ice sheets and glaciers, warming lands and seas, and increased ocean acidity (IPCC, 2023; WMO, 2023). Based on the literature review, (Figure 6) illustrates how unsystematic disposal of municipal solid waste significantly contributes to greenhouse gas emissions, exacerbating climate change. Effective mitigation strategies, such as aerobic composting and landfill gas utilization for energy, along with improved waste management policies, are crucial in reducing the environmental impact and promoting sustainable development.

4.3. Limitations of the Study

This study, although thorough, has several limitations. It is geographically confined to the Chilmish Dass dumping site in Gilgit Baltistan, which may not fully represent the broader waste management issues across the entire region. The study period, limited to June 2022, may not account for seasonal variations in waste generation and their impacts on soil properties. Additionally, the scope of the research was constrained by available resources and access limitations, potentially influencing the comprehensiveness of the data collected. Furthermore, the focus was primarily on the physicochemical parameters of soil, which, while significant, do not cover all potential environmental and health impacts associated with unsystematic waste dumping. Moreover, due to resource constraints, the study did not include an assessment of waste contribution emission rates.

5. Conclusions

This study evaluated the impact of solid waste dumping on the physical and chemical properties of soil around the Chilmish Dass dumping site in Gilgit. The findings revealed that waste dumping significantly affects soil electrical conductivity, organic matter content, and texture. However, no remarkable change was observed in soil pH between the sites. High SOC and SOM levels improve soil fertility by increasing microbial activity, thus enhancing soil productivity for optimal plant growth. In the control site, sand predominates, making it unsuitable for waste disposal. The pH values around both sites are normal and show no significant variability, indicating good soil health. The silt and sand ratios are higher at both sites, affecting water-holding capacity and moisture content.

Unsystematic dumping of solid waste contributes to climate change through anaerobic decomposition, producing potent greenhouse gases like methane (CH4), which has a global warming potential significantly higher than carbon dioxide (CO2). Landfill fires further exacerbate the greenhouse effect by releasing substantial amounts of methane and other pollutants. The increase in greenhouse gas emissions accelerates global warming, leading to glacier melting, sea level rise, and altered climate patterns. In mountainous regions like Gilgit-Baltistan, these changes increase the risk of glacier melt, heavy rainfall, and flash floods, severely impacting local ecosystems and communities. These climate changes also decrease agricultural productivity, deplete water resources, and result in biodiversity loss.

Therefore, improving waste management policies is crucial. Promoting sustainable waste management practices such as recycling and enforcing regulations to prevent indiscriminate dumping are essential steps. Improved waste management systems can significantly reduce greenhouse gas emissions and mitigate climate change impacts.

Continued efforts through regular monitoring, feedback, and public education on sustainable waste practices are crucial to enhancing soil quality and ensuring long-term environmental sustainability. By implementing these measures, we can work towards reducing the adverse effects of waste dumping on both soil health and climate stability.

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