ASSESSMENT OF MUNICIPAL SOLID WASTES AND PHYTODIVERSITY AT THE SOLID WASTE DUMPING SITES IN DISTRICT BAJAUR, PAKISTAN

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Abstract

This study aimed to investigate the composition of municipal solid waste (MSW) disposed in the different dumping sites and their impacts on soil and plants in District Bajaur. The collected data showed that the solid wastes disposed in Khar and Inayat Killi have a high content of organic matter. The paper's content in the solid waste was found low in the Sadiq Abad site as compared to other sites of the research area. The plastic, glasses, clothes and metals were found in almost similar quantity in all the monitoring sites. The solid waste dumping site had a unique flora of 46 species belonging to 22 families. The family Asteraceae was found dominant with 9 species followed by Solanaceae with 5 species, Poaceae with 4 species, Amaranthaceae Brassicaceae and Euphorbiaceae with 3 species each. The rest of the families had one or two species. The habit-wise distribution of the flora was led by herbs with 44 species. Theophytes (35 species) and hemicryptophytes (4 species) dominated the life form spectrum. The seasonal availability reveals that the spring (42 species) and summer (41 species) seasons had the maximum number of species. The impacts of MSW on plant life showed that the plants on or near the dumping site were in the worst condition of their health.

Keywords: Floristic composition, biological spectrum, solid wastes, flora

1. Introduction

Solid waste or municipal solid waste, is any substance that is thrown away, rejected, abandoned, unwanted, or superfluous, regardless of whether it is intended for sale or needs to be altered or purified by a separate process (McAllister, 2015; Adnan et al., 2020; Gupta et al. 2023). Anything that is non-liquid or non-gaseous is created as a byproduct of human activity and has the potential to adversely impact the environment (Evode et al. 2021). The characteristics of municipal solid waste are complex and vary depending on several factors including location, culture, legislation, economic growth, and trash management (Abdel-Shafy and Mansour, 2018). Different solid waste types originate from diverse origins and possess distinct qualities, quantities and disposal techniques (Khalid et al. 2022). Some of the waste is toxic and carcinogenic and requires special care for its management and disposal, which is why there is a need to classify wastes according to their source of origin and quantity of production (Dehghani et al. 2021). Based on the source of generation, several environmental researchers have classified solid waste into several categories, including residential, industrial, commercial, nuclear, medical, electronic, commercial, institutional, demolition, and agricultural waste (Nadeem et al. 2016; Gupta et al. 2023). The social status, educational attainment, and infrastructure of a city have a significant influence on the rate at which solid waste is generated (Khan et al. 2016). The big cities are the main producers of solid waste throughout the globe. The developed countries of the world have technologies to recycle solid wastes into useful products. The underdeveloped countries have no such technologies and they dump solid wastes in open spaces (Hoareau et al. 2021). In Pakistan, it is customary to dump MSW in the open places. It causes a serious hazard to soil, groundwater supplies, and the ecosystem in the region that is impacted.

Solid waste contains heavy metals that can have adverse effects on animal health, human health, and soil production (Singh and Kalamdhad, 2011). Because of an ongoing increase in environmental contamination from industrial, agricultural, and municipal sources, heavy metals have significantly harmed the fertility and quality of the soil in the past decade (Rashid et al. 2023). Heavy metals cause physiological anomalies in soils that adversely affect plant growth and their vitality is diminished by heavy metal absorption through the root system (Goyal et al. 2020). Depending on their nature, the hazardous materials in the solid waste are either leaked into subsurface water or wind up in soil-held water. Soil contaminants such as Cd, Cu, Ni, Pb and Zn can change the chemistry of the soil and affect plants and other species that rely on soil for nourishment (Rashid et al. 2023).

The diversity of vegetation is directly influenced by soil characteristics. Many studies show evidence of the seriousness of hazards caused by open waste dumping ultimately affecting the plant life on the planet leading towards an irreversible erosion trend unless the present land use pattern is checked (Ali et al. 2014). Solid waste pollutants serve as an external force affecting the physico-chemical characteristics of soil ultimately contributing to the poor production of vegetation (Ali et al. 2014; Das et al. 2018). First, the pollutants cause an invisible injury to plants by interfering with their natural metabolism, which then leads to the appearance of a visible lesion subsequently (Ali et al. 2014; Taddese, 2019). It is depriving the natural balance of our ecosystem and bearing results beyond any repair. Assessment of soil pollution becomes difficult when contaminants belong to different sources and their products are variably distributed (Murtaza et al. 2014). The chemical properties of soil serve as the main reason for vegetation change. The disturbances of higher intensity sometimes endanger the survival of some species and yield low richness (Ali et al. 2014).

The floristic composition indicates the different types of plant and their distribution in a given area. The presence of all plant species found in a particular area is termed flora while vegetation is related to the relative importance of plant species, population, and distribution in relation to space and time (Haq and Badshah, 2021a, Manan et al. 2022; Haq et al. 2023). Floristic diversity is used to interpret plant species of any geographical area, whether cultivated or wild. Floristic inventory can help us to understand the features of vegetation characteristics and it is important for human existence, economic health, ecosystem function, and stability. The distribution of plant species is a valuable source of information for environmental factors and ecosystem services in a particular habitat (Homeier et al. 2013; Haq and Badshah, 2021b Manan et al. 2022; Haq et al. 2023).

The reviewed literature showed that the MSW of District Bajaur and its impact on soil and plants have not been studied previously. So, there is an immense need to identify and explore the MSW produced and their potential impacts on soil and plant species. The main objectives of the study are; 1) to investigate the municipal solid waste composition of the research sites, 2) to identify the flora of the municipal solid waste sites and 3) to document the impact of municipal solid waste.

2. Materials and Methods

2.1. Study area

Bajaur is the tribal district of Khyber Pakhtunkhwa province located in the northwest of Pakistan. Geographically, it is surrounded by District Mohmand in the southwest, Kunar province of Afghanistan in the northwest, District Dir in the northeast and District Malakand in the southeast. Bajaur shares a 52 Km border with the Afghan province of Kunar. This Border of Bajaur consists of hills, valleys and passes which are caped with snow during the winter season. Latai Sar Pass, Ghakhi Pass, Kaga Pass and Nawa Pass are the famous routes of transportation and communication between the people of Bajaur and the Kunar province of Afghanistan. The climatic conditions remain considerably variable, with snowfall which cape the mountain peaks in the winter and high temperatures in the summer, with monsoon rain falling in July and August (Fig. 1).

2.2.Survey of the area, monitoring of sites, and identification of solid wastes

To assess solid waste and its impact, ten solid waste disposal sites were selected for this study. These sites were Khar, Sadiq Abad, Inayat Killi, Barkhalozu, Laghri, Lawi Sam, Nawagai, Raghagan, Pashat and Qazafi. These areas were visited and monitored. Solid waste was collected and its composition was recorded. The weight percentage of each weight composition was determined with the help of the following formula.

$$X = \frac{\text{weight of each weight composition(kg)}}{\text{Total amount of each waste composition(kg)}} \text{ x } 100$$

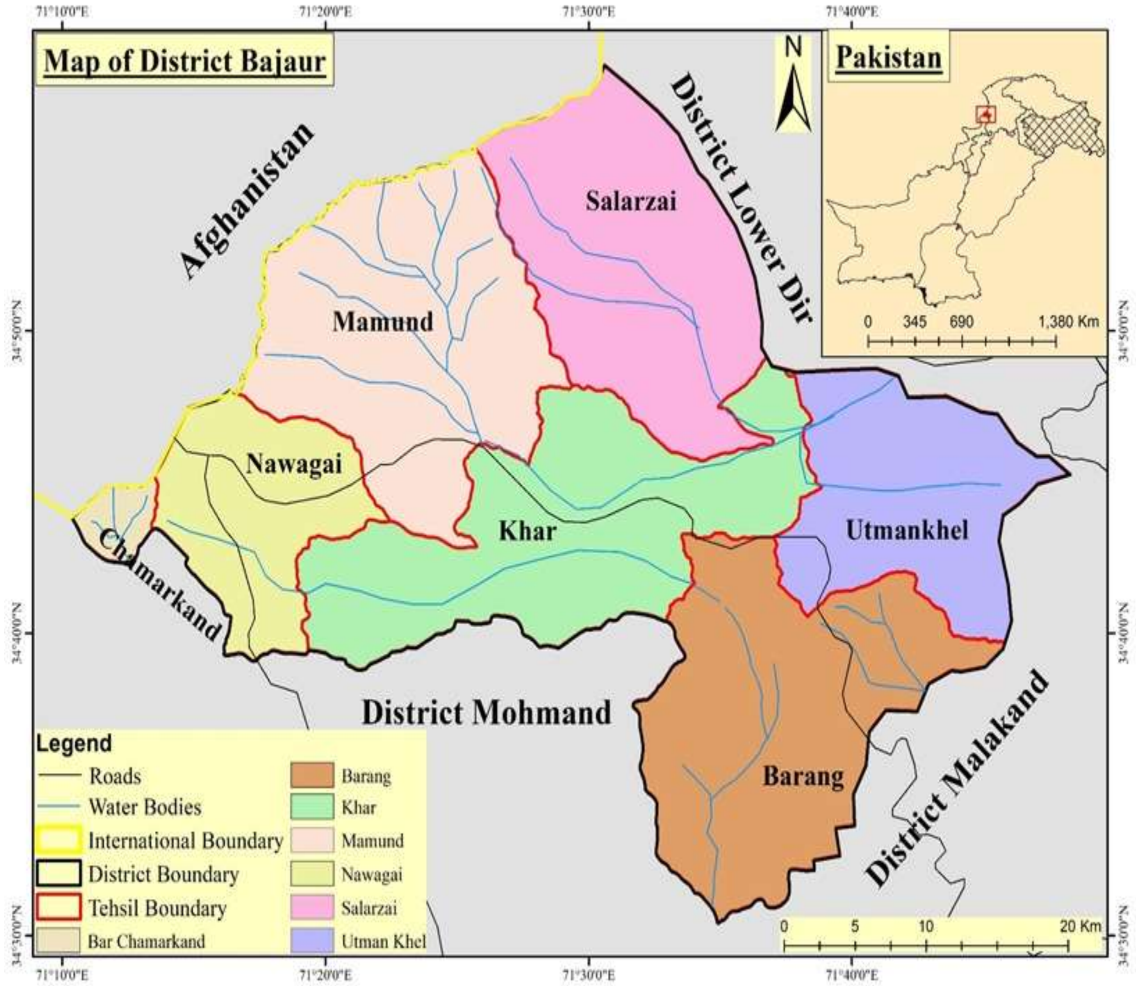

Fig.1. 1 Map of the research area

2.3.Collection of plant specimens and identification

Solid waste dumping sites were surveyed for floristic information. Standard taxonomic techniques were followed for collecting, drying and further processing of the herbarium samples (Maden, 2004). The collected plant specimens were labeled, and placed in blotted pressed, spread over herbarium sheets and identified with the help of Flora of Pakistan (Ali and

Qaiser, 1995-2018). The ecological characteristics of each species were determined with the available literature (Raunkiaer, 1934; Hussain et al. 2015; Haq and Badshah, 2021a; Ghani et al. 2022; Manan et al. 2022; Haq et al. 2023).

2.4.Visual effect of MSW on the plants

To investigate the visual effect of MSW on plant growth, the plants growing on or near the surrounding solid waste and those far away were comparatively studied. At each visit, the growth rate and health condition of the plant were studied with the naked eye, and parallel pictures were also taken on the spot.

3. RESULTS AND DISCUSSION

3.1.Composition of MSW and its effect on soil

The detailed assessment of MSW composition was carried out through the output method of assessment of MSW composition. For this purpose, the aforementioned ten dumping sites were visited. The visual analysis of the solid waste samples collected at the under-consideration sites showed that these solid wastes mainly consist of organic matter (ash and fine earth), followed by paper and a trace amount of plastic, glass and metal. By visual inspection, it was observed that the texture of the soil of the dumping site was considerably different from the nearby control site. The analyzed data shows that the solid waste of Khar and Inayat Killi has a high content of organic matter. The plastic content was found similar in all the monitoring sites. The paper content in the solid waste was found low in the Sadiq Abad site as compared with other sites of the research area The content of glasses, clothes and metals was also found in almost similar concentrations in all the monitoring sites. The ingredients found in the solid waste at the different dumping sites are shown in Table 1 and Fig. 2.

Municipal solid waste (MSW) is a diverse mixture of materials that have been thrown from homes, companies, institutions, and industries. MSW typically consists of organic trash, paper, plastics, glass, metals, textiles, rubber, and various products including electronics and household appliances. Food scraps and yard debris are forms of organic waste that often make up a significant portion of MSW that produce methane in landfills, this contributes to environmental issues (Di Trapani et al. 2013). Plastics make up a significant portion of MSW and provide difficulties for recycling due to their diverse forms and lack of infrastructure (Geyer et al. 2017). Factors such as economic status, population density, cultural norms, and geographic location may have a significant impact on its composition. To solve environmental issues and promote sustainability, it is crucial to understand the chemistry of MSW to develop efficient waste management initiatives, such as recycling, composting, and waste-to-energy projects.

Table 1. Composition of MSW in Bajaur

S#	Site name	Organic matter, ash and soil	Plastic	Paper	Glass	Cloths	Metal
1	Khar	+++++	+++	++	+	+	+
2	Sadiq Abad	+++	+++	+	+	+	+
3	Inayat Killi	++++	+++	++	+	+	+
4	Barkhalozai	++	+++	++	+	+	+
5	Lagari	++	+++	+++	+	+	+
6	Loi Sam	++	+++	++	+	+	+
7	Nawagai	++	+++	++	+	+	+
8	Raghagan	++	+++	++	+	+	+
9	Pashat	+++	+++	++	+	+	+
10	Qazafi	+++	+++	+++	+	+	+

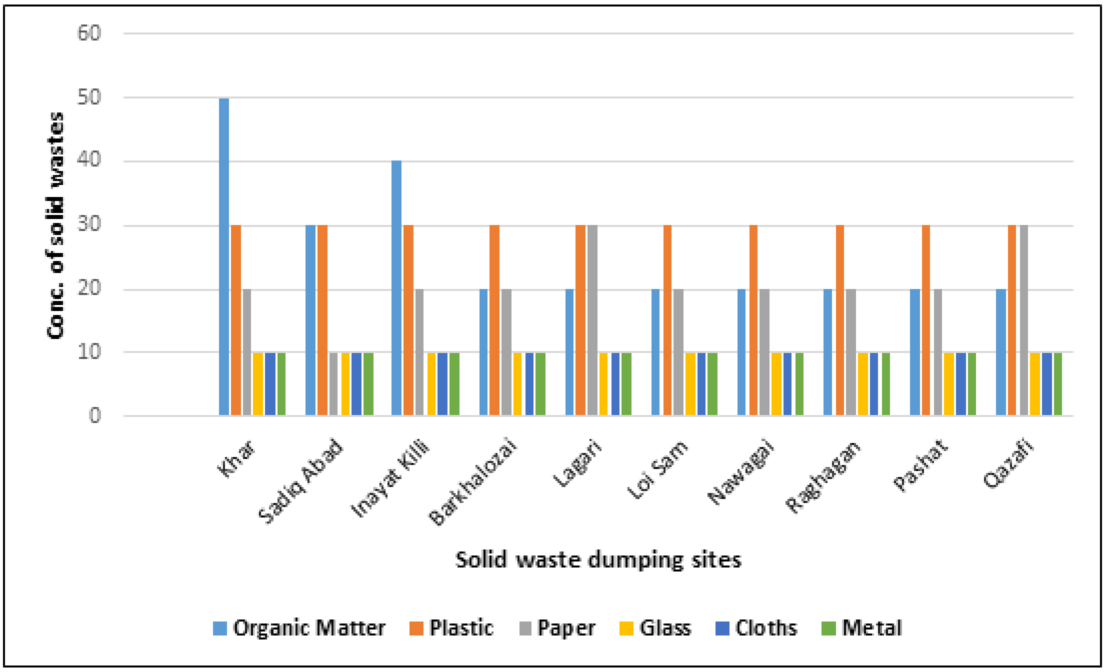

Fig.2. Municipal Wastes in Bajaur

3.2. Flora of MSW sites

The flora of the MSW disposal site was documented which consists of 46 species belonging to 22 families. The dominant family was Asteraceae with 09 species followed by Solanaceae with 5 species, Poaceae with 4 species, Amaranthaceae, Brassicaceae and Euphorbiaceae with 3 species each. The rest of the families contributed only one or two species (Table 2, Fig. 3). The dominance of the family Asteraceae, in a particular area can significantly impact its ecological dynamics. Asteraceae is the most dominant family in the angiosperm having a wide distribution across the various habitats. Its dominance in a particular area is attributed to several reasons, including its capacity to quickly colonize new habitats, extensive reproductive strategies with prolific seed production, the non-palatable nature of most species, adaptation to changes in the environment, and outcompete other plant species as well (Hussain et al. 2016; Sherwani, 2020; Haq and Badshah, 2021a, Ali et al. 2022; Ghani et al. 2022; Haq et al. 2023). Many Asteraceae plants exhibit allelopathic effects, which influence the distribution and growth of nearby plant species (Lopes et al. 2022). The habit of the flora was dominated by herbs with 44 species. High moisture availability, nutrient-rich soils, and moderate disturbance regimes are some of the characteristics of municipal solid waste habitats that favour the growth of herbs. Compared to woody plants, herbs grow more quickly and reproduce more frequently, which enables them to quickly colonize and take advantage of resources in ecosystems. (Spicer et al. 2022).

The life form was dominated by therophytes with 35 species and hemicryptophytes with 4 species (Fig. 4). Therophytes, having short life cycles and are able to complete their life cycle in a single growing season, frequently appear in highly disturbed habitats like urban landscapes, agricultural fields, and recently burned areas. They can quickly colonize open habitats by taking advantage of transient favourable conditions due to their rapid germination, development, and reproduction strategies (Schippers et al. 2001). The seasonal availability reveals that the spring (42 species) and summer (41 species) seasons had more no of species (Fig. 5). The dynamics of an ecosystem can be greatly affected by the seasonal availability of some plant species, particularly during the spring and summer. During these seasons, these species typically exhibit adaptations to take advantage of favourable conditions such as greater exposure to sunlight, warmer temperatures, and sufficient moisture availability (Silveira and Thiébaut, 2017). Early emergence and quick growth are two tactics that spring-flowering species frequently employ to increase reproductive success before the start of the summer drought or competition with later-flowering species. However, summer-dominant species might have evolved to endure stress from water and heat, which would allow them to thrive and reproduce during the warmer months (Cho et al. 2017). The high moisture content of MSW promotes the growth of herbaceous flora, however heavy metal concentrations and the rough soil texture of MSW are the things that prevent the development of lush greenery.

Table 2 Flora of the different municipal solid waste dumping (MSWD) sites in district Bajaur

S#	Species name	Family	Habit	Life form	Sp	Su	Au	Win	Flowering phenology
1	*Achyranthes aspera* L.	Amaranthaceae	Hb	Th	-	-	+	+	Apr-May
2	*Adiantum capillus-veneris* L.	Adianceae	Hb	Hem	+	+	+	+	Jun-Jul
3	*Amaranthus spinosus* L.	Amaranthaceae	Hb	Th	–	+	–	–	Apr-May
4	*Amaranthus viridis* L.	Amaranthaceae	Hb	Th	–	+	-	-	Apr-May
5	*Avena fatua* L	Poaceae	Hb	Th	+	+	-	-	Mar-Apr
6	*Calendula arvensis* L.	Asteraceae	Hb	Th	+	-	-	-	Mar-Apr
7	*Cannabis sativa* L.	Cannabaceae	Hb	Th	+	+	-	-	May-Jun
8	*Capsella bursa-pastoris* (L.) Medik.	Brassicaceae	Hb	Th	+	+	-	-	Mar-Apr
9	*Chenopodium album* L.	Chenopodiaceae	Hb	Th	+	+	+	-	May-Jun
10	*Chenopodium botrys* L	Chenopodiaceae	Hb	Th	+	+	+	-	Apr-May
11	*Cichorium intybus* L.	Asteraceae	Hb	Th	+	+	+	+	Jul-Aug
12	*Citrullus colocynthis* (L.) Schrad.	Cucurbetaceae	Hb	Th	+	-	-	-	Mar-Apr
13	*Cleome viscosa* L.	Capparidaceae	Hb	Th	+	+	+	-	Jun-July
14	*Conyza canadensis* (L.) Cronquist.	Asteraceae	Hb	Th	+	+	-	-	May-July
15	*Cynodon dactylon* (L.) Pers	Poaceae	Hb	Hem	+	+	+	-	May-Jul
16	*Cyperus rotundus* L.	Cyperaceae	Hb	Geo	+	+	+	-	May-Jun
17	*Datura innoxia* Mill.	Solanaceae	Sb	Ch	+	+	+	-	Apr-May
18	*Datura stramonium* L	Solanaceae	Sb	Np	+	+	-	-	Apr-May
19	*Euphorbia helioscopia* L.	Euphorbiaceae	Hb	Th	+	+	+	-	Mar-Apr
20	*Euphorbia hirta* L.	Euphorbiaceae	Hb	Th	+	+	+	+	Jul-Aug
21	*Euphorbia prostrata* Ait.	Euphorbiaceae	Hb	Th	+	-	-	-	Mar-Apr
22	*Fumaria indica* (Hausskn.) Pugsely.	Fumariaceae	Hb	Th	+	+	-	-	Mar-Apr
23	*Lepidium apetalum* Willd.	Brassicaceae	Hb	Th	+	+	-	-	Mar-Apr
24	*Moraea sisyrinchium* (L.) Ker Gawl	Iridaceae	Hb	Geo	+	-	-	-	Mar-Apr
25	*Oxalis corniculata* L.	Oxalidaceae	Hb	Th	+	+	+	-	Mar-Apr
26	*Parthenium hysterophorus* L.	Asteraceae	Hb	Th	+	+	+	+	W. year
27	*Phalaris minor* Retz	Poaceae	Hb	Th	+	+	+	-	Mar-Apr
28	*Physalis divaricata* D. Don.	Solanaceae	Hb	Th	-	+	+	-	Jul-Aug
29	*Plantago lanceolata* L. P	Plantaginaceae	Hb	Th	+	+	-	-	Apr-May

30	*Plantago major* L.	Plantaginaceae	Hb	Th	+	+	-	-	Jun-Jul
31	*Poa annua* L.	Poaceae	Hb	Hem	+	+	+	-	Mar-Apr
32	*Polygonum aviculare* L.	Polygonaceae	Hb	Th	+	+	+	-	May_ Jun
33	*Ranunculus muricatus* L.	Ranunculaceae	Hb	Geo	+	+	-	-	Mar-Apr
34	*Silybum marianum* (L.) Gaertn	Asteraceae	Hb	Ch	+	+	-	-	Apr-May
35	*Sisymbrium irio* L.	Brassicaceae	Hb	Th	+	+	-	-	Mar-Apr
36	*Solanum nigrum* L.	Solanaceae	Hb	Th	+	+	-	-	Apr-May
37	*Solanum surattense* Brum.f.	Solanaceae	Hb	Th	+	+	-	-	Apr-Aug
38	*Sonchus asper* (L.) Hill.	Asteraceae	Hb	Th	+	+	+	-	Mar-Apr
39	*Sonchus oleraceus* L.	Asteraceae	Hb	Th	+	+	+	-	May-Jun
40	*Stellaria media* (L.) Vill.	Caryophyllaceae	Hb	Th	+	+	-	-	Apr-May
41	*Taraxacum officinale* Webber.	Asteraceae	Hb	Th	+	+	-	-	Mar-Apr
42	*Tribulus terrestris* L.	Zygophyllaceae	Hb	Hem	+	+	+	-	W-Year
43	*Trichodesma indicum* (L.) R. Br., Prodr.	Boraginaceae	Hb	Th	+	+	+	-	Apr-May
44	*Vicia hirsuta* (L.) S.F. Gray, Nat.	Papilionaceae	Hb	Th	+	+	-	-	Apr-May
45	*Vicia sativa* L.	Papilionaceae	Hb	Th	+	+	-	-	Jun-July
46	*Xanthium strumarium* L.	Asteraceae	Hb	Ch	+	+	-	-	Jun-Jul

Key: **Habit**- Hb= Herb, SB= shrub, **Life form**- Th= Therophyte, Np= Nanophanerophytes, Hem= Hemicrypytophytes, Ch= Chemaephytes, Geo= Geophytes

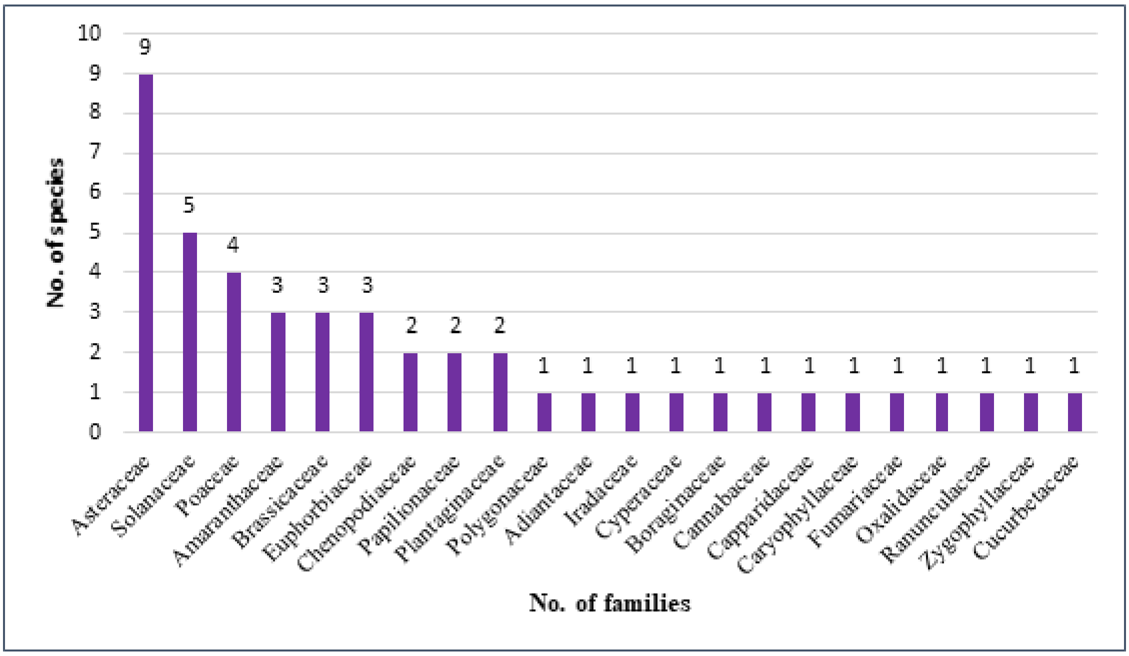

Fig.3. Familywise distribution of species

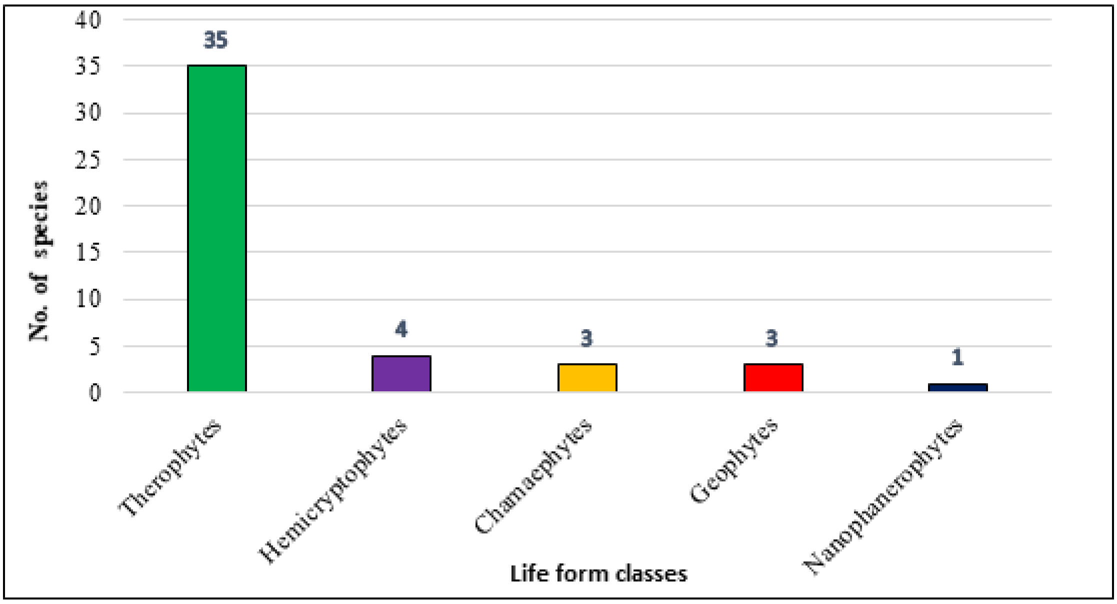

Fig.4. Life form distribution of species

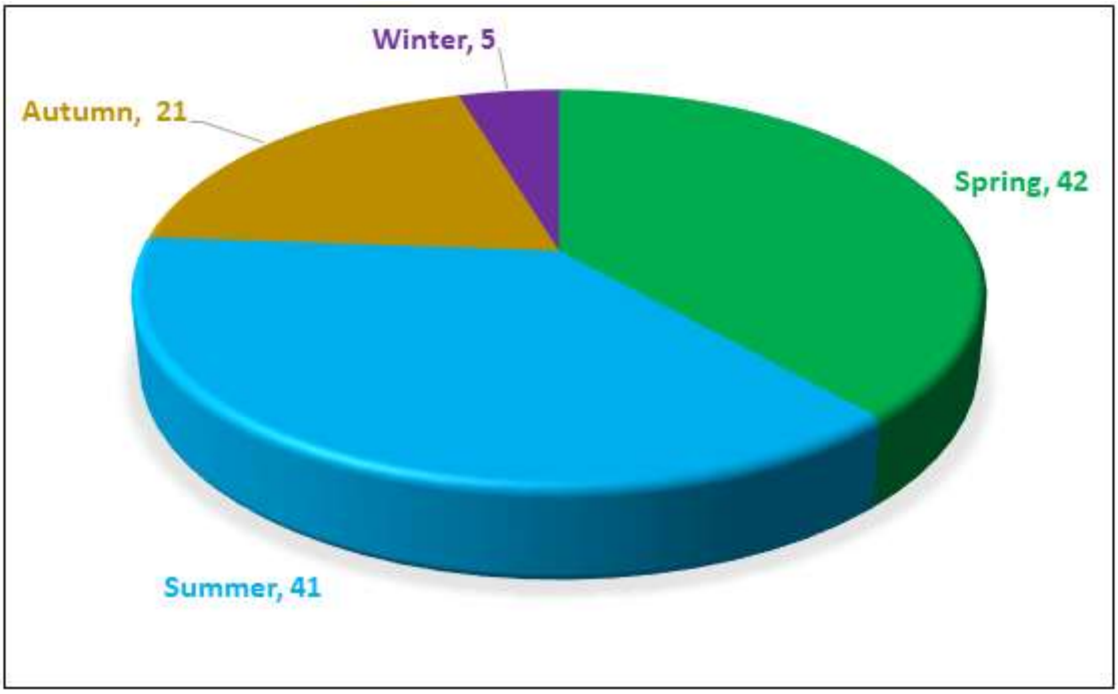

Fig.5. Seasonal availability of species

3.3.Impacts of MSW on the flora of the dumping sites

Municipal Solid Waste (MSW) has extensive and varied effects on the vegetation of surrounding disposal sites. During the present study, it was found that certain species, such as *Parthenium hysterophorus*, *Silybum marianum* and *Xanthium strumarium* flourish well by taking advantage of disturbed habitats. Other nearby plants exhibit stunted growth and leaves with dull yellow coloration. It was also observed that the MSW modifies the structure and texture of the soil, which negatively impacts the overall plant development of the area. Municipal wastes have varied effects on soil physico-chemical properties which directly or indirectly affect the plant growth and development. MSW accumulation change the composition and structure of the soil, which affects microbial populations, pH levels, and nutrient availability and such modifications can have a negative impact on plant diversity and growth (Suthar, 2017). Organic matter in MSW decomposes to produce leachates that contain contaminants with pesticides, heavy metals, and organic compounds. All of these contaminants can seep into the soil and have an adverse impact on plant growth (Sharma et al. 2022). In addition, the physical existence of solid waste restricts the growth and development of native plant species by obstructing sunlight, preventing water flow, and restricting root penetration. This encourages the growth of opportunistic and invasive plant species that are adapted to disturbed habitats (Qasim et al. 2020). In general, the presence of MSW in disposal sites is a serious threat to the plants, which lowers biodiversity and creates ecological imbalances within such habitats.

Pictorial view of plants of MSW

4. CONCLUSION

This research was conducted to assess the MSW impacts on soil and plants. It was concluded that accumulation of MSW for a long period over the dumping site alters the soil properties that directly affect plant growth and development. Plants exactly above the dumping site or close to it had the worst health conditions. These plants had very small leaves, with yellow to greenish-yellow in colour. However, lush green plants with healthy growth were found away from the duping site. The organic matter from the dumping site soil is leached into the field with water, resulting in the sandy and clayey soil becoming more fertile as well as capable of holding more water. It has been suggested that modern technology and appropriate management be required for the recycling of municipal solid waste.

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