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Granulometric composition of Astana's soil

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Abstract: Understanding the granulometric composition of urban soil is essential for assessing pollution levels and managing soil resources effectively. The particle-size distribution of soil significantly affects the movement and accumulation of pollutants, water infiltration, chemical interactions, and biological processes, including microbial activity and nutrient cycling. This study investigated the mechanical composition of soils in Astana by collecting samples from 60 sites across various administrative districts, including Esil, Baikonur, Almaty, Saryarka, and Nura. The analysis showed that heavy loamy soils dominate throughout the city. The average clay content in the soil samples was 44.9% in Esil, 45.7% in Baikonur, 45.0% in Almaty, 42.6% in Saryarka, and 45.4% in Nura. These types of soils are beneficial for agricultural and landscaping purposes because they retain moisture and nutrients well. However, they also have limitations, such as a higher susceptibility to erosion, anthropogenic contamination, and reduced permeability under dry conditions, which may affect vegetation growth. Given these challenges, proper management strategies are needed to protect urban soils from degradation and ensure long-term functionality. The results of this research provide valuable data for environmental zoning and decision-making. They can support sustainable land use planning, pollution prevention, and long-term soil quality monitoring in Astana, contributing to the city's ecological safety, resilience, and green infrastructure development.

Keywords: soil, granulometric composition, soil fertility, urbanisation, anthropogenic impact.

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1. Introduction

Intensification of urbanisation in the last decades is bringing new environmental problems and challenges, as population growth concentrates population, activities, and infrastructures in increasingly large urban areas.

Urban expansion and the activities associated have significant impacts on land use and soil health: urban growth and infrastructures occupy and/or destroy fertile soils, which are also sealed and/or compacted, submitted to pollution processes from industry and traffic, as well as from waste disposal (Béchet et al., 2019). Since the middle of the 20th Century, the global urban population has been rapidly increasing, from 751 million individuals in 1950 to an estimated 4.2 billion in 2018, which accounts for roughly 55% of the total global population (United Nations, 2018).

It has been estimated that whilst less than 0.5% of the total global land surface is covered in built-up urban developments, this small percentage represented a total of 0.5 million km2 at the turn of the last century (Goldewijk et al., 2010), although estimates vary (Potere and Schneider, 2007).

These urban ecosystems not only provide services to their inhabitants but are also often hotspots for global change factors such as increased temperature (Arnfield, 2003), salinisation (Equiza et al., 2017), and the presence of pollutants such as heavy metals (Plyaskina and Ladonin, 2009). Hence, urban soils can provide valuable information when it comes to understanding the impacts of global change factors on soil ecosystems and their functioning, which might impact human health (Brevik and Burgess, 2014).

In these systems, anthropogenic interference is commonplace; this can include the management of soils (e.g. mowing and irrigation in urban parks), transportation of soils (e.g. due to construction; Hooke, 2000), soil sealing, and the addition of waste and construction material, such as building sand (Bridges, 1991). Urban landscapes have previously been associated with generally high levels of compaction (Lehmann and Stahr, 2007), although this may only be true in localised areas of high intensity usage (Edmondson et al., 2011).

Urban soils provide a range of important ecosystem services themselves, such as hydrological control through infiltration, and as the substrate for plant growth (Morel et al., 2015).

Via this impact on local flora, they not only support food production but also the parks and green spaces which have been demonstrated to support the wellbeing of urban residents (Tzoulas et al., 2007; Diaz et al., 2018).

Inputs of fertilisers, elevated levels of N deposition and altered irrigation, as well as the removal of organic matter, cause altered nutrient cycling compared to natural ecosystems (Lorenz and Lal, 2009), with the new equilibrium varying across climatic regions, parent materials and socioeconomic areas (Pickett et al., 2001).

The functioning of soil is closely related to its structure, which determines the availability of air, water, nutrients, and pollutants to the microbial life that inhabits it. In addition, the granulometric composition of soil is one of the key factors that directly influences both the level of contamination by toxic substances and the soil's self-purification capacity. Therefore, to objectively assess the contamination status of soil, it is first necessary to determine its mechanical composition. Based on this scientific rationale, a research study was conducted to determine the granulometric composition of the soil in the city of Astana. To achieve the goal of the study, soil structure analyses were carried out for each administrative district of the city, and zoning work was implemented (Gálos et al., 2007).

The results of the granulometric analysis indicated a predominance of heavy loamy soils throughout Astana's territory. Such soils typically contain a high proportion of fine particles (silt and clay), which enhance their water retention capacity and nutrient-holding properties. While these characteristics make them favourable for certain types of land use, such as green landscaping and limited urban agriculture, they also present specific management challenges. For instance, heavy loamy soils are more susceptible to waterlogging and compaction, particularly in areas with high foot or vehicle traffic, which can impede root development and diminish soil aeration (Hiemstra et al., 2003).

Additionally, these soils are more likely to accumulate pollutants, including heavy metals, hydrocarbons, and excess salts, especially in areas adjacent to roads, industrial zones, or poorly managed waste disposal sites. This accumulation arises from their smaller pore spaces and lower permeability, which slows the movement of contaminants and facilitates their binding to soil particles. Therefore, regular monitoring of chemical contamination in such areas is essential to prevent long-term degradation and protect urban biodiversity and human health (Li, X. et al., 2018).

Understanding the granulometric composition also plays a crucial role in urban planning and environmental zoning. By identifying soil types and their vulnerabilities, urban developers and municipal authorities can make informed decisions regarding infrastructure placement, green space allocation, and pollution mitigation strategies. For example, areas with fine-textured soils may require specific engineering approaches to reduce runoff and increase infiltration or may be prioritised for green infrastructure development such as bioswales or rain gardens (Zhu, Y et al., 2019).

Moreover, this data can serve as a baseline for future environmental assessments, providing a scientific reference point to evaluate changes over time due to urban expansion, climate change, or remediation efforts. In this context, the integration of soil studies into broader urban sustainability frameworks becomes vital. Ultimately, the research conducted in Astana underscores the importance of incorporating detailed soil analysis into city planning processes to foster resilient, healthy, and ecologically sustainable urban environments.

2. Materials and Methods

The city of Astana is situated in the northern region of Kazakhstan, along the Ishim River. Its geographical coordinates are 51°11′ N latitude and 71°25′ E longitude. The climate is sharply continental. Winters are cold and last for 5 to 5.5 months, with snow cover typically present from mid-November for approximately 130–140 days. The average temperature in January is - 17°C, while the average temperature in July ranges from 20°C to 24°C. Summers are hot and dry, accompanied by occasional dust-laden winds. Maximum temperatures can reach 35°C. The average wind speed in Astana is 5 m/s, and the average annual precipitation is 200–300 mm.

The city of Astana is divided into several administrative districts (Figure 1). Each district is distinguished by its own infrastructure and social status. Almaty District was founded on May 6, 1998. The land area is 154.71 km^2. The number of inhabitants is 402,547. Saryarka district was established on May 6, 1998. 67.76 km^2. The number of inhabitants is 351,118. Baikonur district was established on February 26, 26.02.2018. The area is 181.29 km^2. The population is 228,378. Esil district - Esil district was established on August 5, 2008. The area is 200.22 km^2. The number of inhabitants is 287,035. Nura district - the district was established in 2022. The area is 181.29 km^2. The population is 233,024.

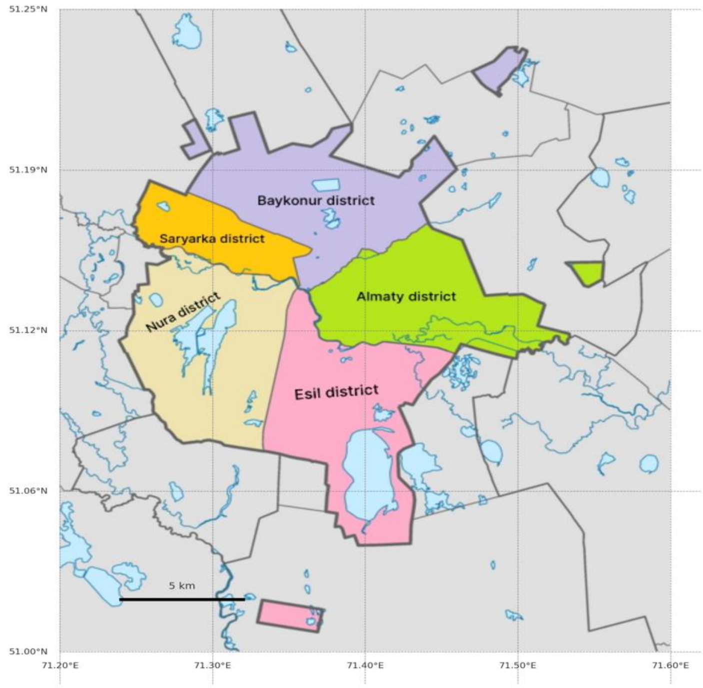

Figure 1. Administrative districts of Astana (as of 2023)

According to the geographical zoning of soils, the territory of Astana city belongs to the type of dark chestnut soils (Redkov, 1961; Uspanov, 1967). The soil cover of Astana city consists of the following types: dark chestnut soils and their varieties, meadow-chestnut soils and their varieties, solonetz soils, and urban soils (urbanozems). The majority of the city's soil cover has undergone technogenic changes under the influence of anthropogenic pressures. This situation can be associated with intensive construction and the impact of industrial enterprises. Additionally, long-term snow cover and deep soil freezing also affect the soil formation process.

According to studies conducted on the soil cover of Astana city (Development plan of Astana city until 2035), it was determined that urbanised soils occupy 40-50% of the city's soils. The mentioned urbanised soil cover was divided into two types. Completely transformed soils (typical urbanozems) mainly cover the central part of the city. They are heavily compacted, mixed with crushed stone, various wastes, and covered with asphalt, concrete, and special pavements. Partially transformed soils (with transitional differences) are found in the peripheral areas of the city and on new construction sites. These soils consist of a mixture of natural soil with construction, household, and plant waste during the construction process (see Figure 3).

The soil cover of Astana city to a depth of 50 cm, characteristic of the urbanisation process, contains about 5% anthropogenic inclusions (construction and household waste, industrial residues). Additionally, technogenic deposits and dusty atmospheric sediments accumulate in the surface layer of the soil cover. This phenomenon is mainly typical for industrial zones, major highways, and district heating plant areas. Meanwhile, soils that have preserved their natural state are found in areas adjacent to forests, parks, riverbanks, and reserve categories of land.

The master plan for Astana city until 2035 includes the following measures aimed at preserving the natural condition of the soil cover, eliminating pollution, and restoring the soil:

- Allocating undamaged sites ("cores") unaffected by anthropogenic activities that can be used for creating landscapes with natural soil and vegetation;
- Land reclamation;
- Design and exploratory works: soil research and other field studies, laboratory analysis, and cartography;

- During construction, removing, transporting, and preserving the fertile soil layer; placing potentially fertile rocks and layers in restoration areas; maintaining and replenishing fertility annually through the application of mineral fertilisers;
- Monitoring land pollution and developing protective measures;
- Creating suitable planting sites with new soil for trees and lawns;
- Controlling pollutant emissions and preventing soil contamination.

Soil samples for granulometric composition analysis were taken from a depth of 0–30 cm, based on clause 4.4 of the standard ISO 12536-2014.

To determine the granulometric composition, the soil sample undergoes a dispersion procedure that fully separates soil particles from aggregates and allows for the identification of their true mechanical composition. The dispersion process involves mechanical (physical) and chemical methods.

Using this method, the mechanical composition of the soil (sand, silt, clay) is identified, which helps describe its agronomic properties. The procedure must be performed in accordance with the ISO 12536-2014 standard.

The sizes of mechanical elements in the soil vary depending on the soil formation process. Soil particles of various sizes define specific soil properties. These properties are distinct and sharply variable, which led to their classification into groups or fractions. This classification is called mechanical fractionation. Currently, N.A. Kachinsky's classification is widely used in science (see Table 1).

There are several classifications based on the volume of soil fractions.

The first classification is simple: particles larger than 1 mm are called the soil skeleton, and particles smaller than 1 mm are called fine soil.

The second classification is more significant and classifies the soil by granulometric composition: particles larger than 0.1 mm are physical sand, particles smaller than 0.01 mm are physical clay.

Clay and clayey soils are better supplied with nutrients and humus and are better connected than sandy soils, with higher moisture capacity. That is, the reserves of moisture and nutrients in clay and heavy clay soils better support plant productivity. However, these soils require more energy and cost for cultivation and special care. Such soils are prone to water erosion and can lose fertility if neglected.

3. Results

Soil samples were collected in 2023 from 60 different locations across the territory of Astana city to analyse the granulometric composition of the soil.

To determine the mechanical and agrochemical composition of Astana city's soil, a total of 60 soil samples were taken. The sampling points covered all residential districts of the city, including Almaty, Saryarka, Esil, Baikonur, and Nura (see Figure 2).

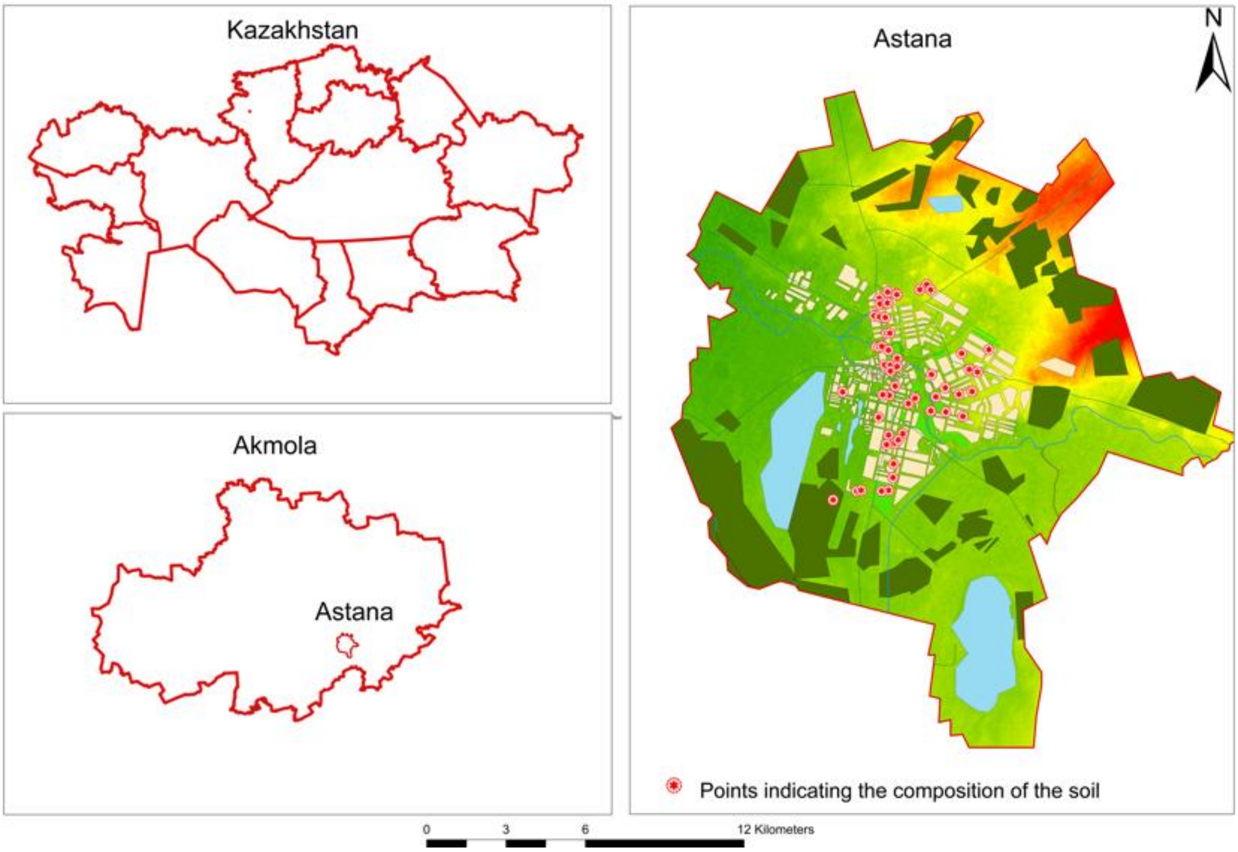

Figure 2. Sampling locations in Astana city for determining the granulometric and agrochemical composition of the soil

Clay content analysis of soil samples from 12 points within the Esil district yielded the following results (Table 1, Figure 3). In this district, the average clay percentage in the soil was 44.9%, indicating heavy clay soil. The lowest value was recorded at point 2 (N 51.185385, E 71.405608) with 29.3%, which corresponds to light clay soil. The highest value was observed at point 11 with 49.9%, indicating heavy clay soil.

Table 1. Granulometric composition (%) of soil in the Esil district (2023) (mg/kg)

№	Coordinates N, E	1-0.5	0.5-0.25	0.25-0.1	0.1-0.05	0.05-0.01	0.01-0.002	0.002-0.001	Less than 0.001
1	N 51.131297, E 71.504347	0.7408	2.2242	2.8729	27.1425	15.8744	18.9149	7.0185	25.2118
2	N 51.156562, E 71.413823	0.8545	2.3687	2.7946	47.7272	16.9474	8.4752	6.6467	14.1857
3	N 51.156188, E 71.421675	0.9802	2.1475	2.2364	33.4184	16.4494	12.7483	6.3149	25.7049
4	N 51.151601, E 71.415371	0.8611	2.1054	2.9748	31.2691	16.6145	16.5734	7.7833	21.8184
5	N 51.147582, E 71.421822	0.8478	2.941	2.2874	42.2679	13.0282	11.1471	6.7495	20.7311
6	N 51.146995, E 71.415454	0.8129	1.8527	2.4311	33.1242	17.1648	15.1218	7.5181	21.9744
7	N 51.144376, E 71.419896	0.8821	2.7487	2.6487	33.4902	16.9712	16.1724	6.8127	20.274

8	N 51.135886, E 71.437816	0.782	2.4197	2.3714	31.2811	17.0847	11.1456	6.1149	28.8006
9	N 51.129057, E 71.431707	0.8215	2.4141	2.2784	28.6149	16.9042	13.1907	6.1746	29.6016
10	N 51.126125, E 71.414594	0.8384	2.1149	3.8497	29.5173	14.6474	12.7946	6.849	29.3887
11	N 51.130670, E 71.408821	0.8134	2.2115	2.8049	32.7219	11.481	14.3249	6.0918	29.5506
12	N 51.131117, E 71.404956	0.6193	2.9147	2.6131	33.4217	12.482	12.8921	6.7132	28.3439

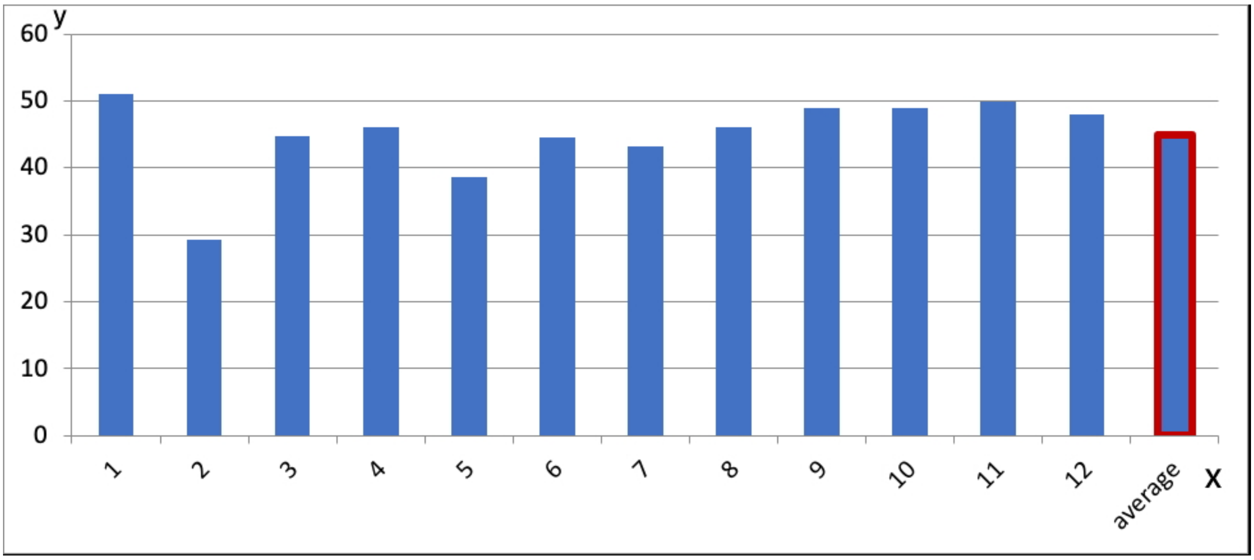

Figure 3. Clay content (%) in the soil of the Esil district

Soil samples taken from 12 locations in the Baykonur district revealed that the average clay content was 45.7%, which corresponds to heavy clay according to N.A. Kachinsky's classification. The lowest clay content was recorded at point 9 (N 51.165812, E 51.408003) with 36.2%, indicating medium clay. The highest clay content was found at point 11 (N 51.158153, E 51.405402) with 51.7%, characteristic of light clay soil (Table 2, Figure 4). Additionally, point 7 (N 51.174650, E 51.412181) also showed characteristics typical of light clay soil.

Table 2. Granulometric composition (%) of soil in the Baykonur district (2023) (mg/kg)

№	**Coordinates N, E**	**Physical clay content, %**							
		1-0.5	**0.5-0.25**	**0.25-0.1**	**0.1-0.05**	**0.05-0.01**	**0.01-0.002**	**0.002-0.001**	**Less than 0.001**
1	N 51.190381, E 71.451860	0.9311	1.4051	1.0744	43.1338	15.4061	18.0854	4.4025	15.5615
2	N 51.190286, E 51.401785	0.8316	1.2875	1.9781	33.2794	18.645	16.2784	6.2481	21.4516
3	N 51.176048, E 71.400771	0.7892	2.2491	2.0312	29.2581	16.2894	12.8416	8.2319	28.3095
4	N 51.175604, E 71.405662	0.8215	1.9481	3.1284	27.8561	18.3492	11.4219	9.1576	27.3172
5	N 51.175125, E 71.410764	0.8384	2.4819	4.8497	30.4653	19.7564	12.7946	7.8419	20.9718
6	N 51.174416, E 71.410961	0.7134	2.9215	2.0809	32.3719	12.4814	15.3829	7.0918	26.9582

7	N 51.174650, E 71.412181	0.5149	1.9917	2.0631	31.4972	13.0742	14.1126	6.8872	29.8591
8	N 51.165788, E 71.415026	0.7785	2.5314	1.7519	36.2711	11.0492	5.0121	8.6716	33.9342
9	N 51.165812, E 71.408003	0.8215	1.7315	2.7287	44.2067	14.2405	14.1716	6.0571	16.0424
10	N 51.158699, E 71.402973	0.8201	1.8942	2.5516	37.0945	12.7403	14.9902	6.1875	23.7216
11	N 51.158153, E 71.405402	0.8106	2.1054	2.0781	33.2691	15.0645	13.2134	6.748	26.7109
12	N 51.157965, E 71.407898	0.6802	2.3471	2.8376	27.2144	15.2094	11.9418	7.3345	32.435

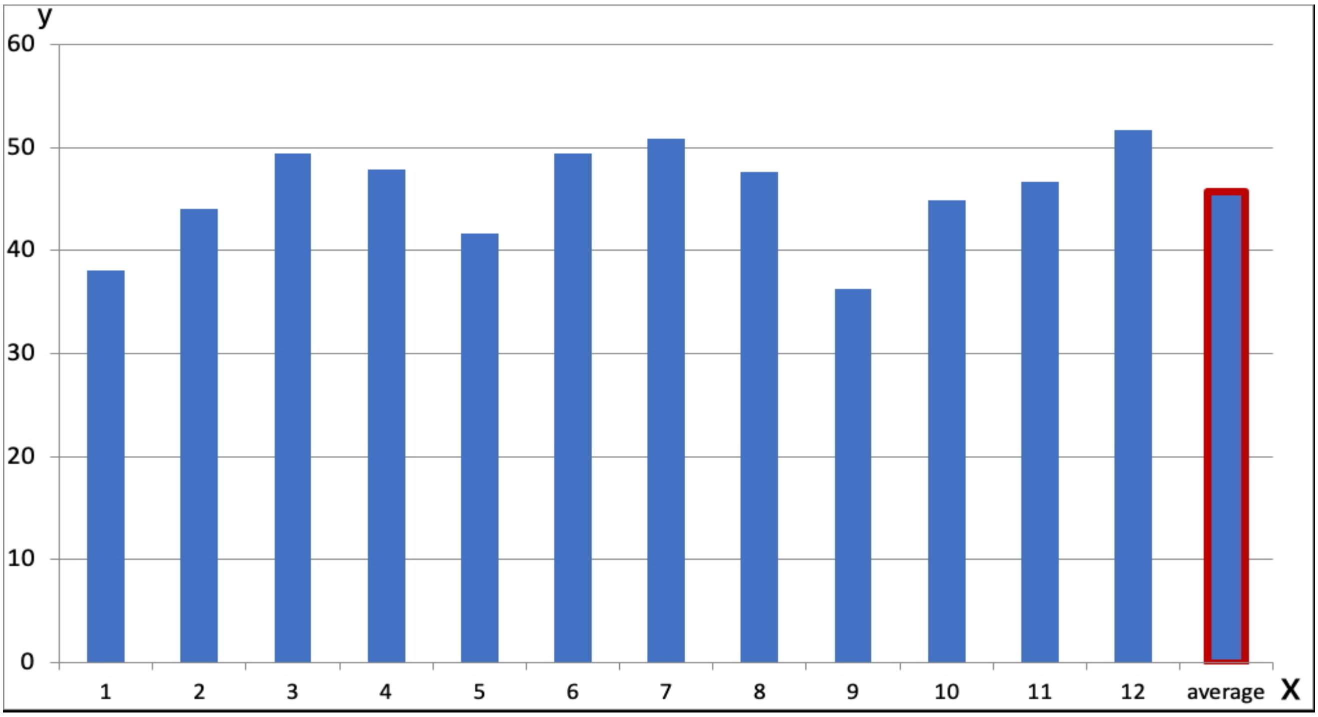

Figure 4. Clay content (%) in the soil of the Baykonur district

The average clay percentage in the granulometric structure of the soil in the Almaty district was found to be 45%, indicating heavy clay soil (Table 3, Figure 5). Medium clay structure was observed at two points (points 2 and 7), while light clay structure was identified at points 3 and 6.

Table 3. Granulometric composition (%) of soil in the Almaty district (2023) (mg/kg)

№	Coordinates N, E	Physical clay content, %							
		1-0.5	0.5-0.25	0.25-0.1	0.1-0.05	0.05-0.01	0.01-0.002	0.002-0.001	Less than 0.001
1	N 51.158374, E 71.410329	0.6999	1.5415	2.4581	45.4485	0.9039	2.4025	0.4460	46.0994
2	N 51.147887, E 71.486624	0.5245	1.2654	2.2478	61.2950	0.8034	1.2149	0.1715	32.4775
3	N 51.145361, E 71.494109	0.8425	2.1701	2.3121	31.1011	12.0149	14.3716	6.1875	31.0002
4	N 51.143864, E 71.489106	0.8764	2.8942	3.7416	34.4975	14.3491	13.4972	8.1875	21.9565

5	N 51.132936, E 71.456477	0.8213	2.3802	1.9851	31.3612	14.3341	14.0211	5.9892	29.1078
6	N 51.129879, E 71.452480	0.8288	2.3709	1.9114	29.2944	12.9871	16.7467	6.9709	28.8898
7	N 51.122063, E 71.465574	0.8391	1.3717	2.467	33.4902	15.5712	16.264	6.1827	23.8141
8	N 51.121332, E 71.451997	0.8755	2.1367	2.0719	37.7121	17.2094	8.1112	6.1667	25.7165
9	N 51.121918, E 71.480924	0.8248	1.7194	2.1128	40.2706	12.5402	12.6711	6.1705	23.6906
10	N 51.118808, E 71.479771	0.8129	1.8527	2.4311	33.1242	17.1648	15.1218	7.5181	21.9744
11	N 51.154358, E 71.465045	0.7512	2.8642	2.0946	25.0842	22.5317	15.4072	6.1892	25.0777
12	N 51.134981, E 71.477349	0.8413	2.1852	2.0816	32.9713	17.8146	14.9329	6.8019	22.3712

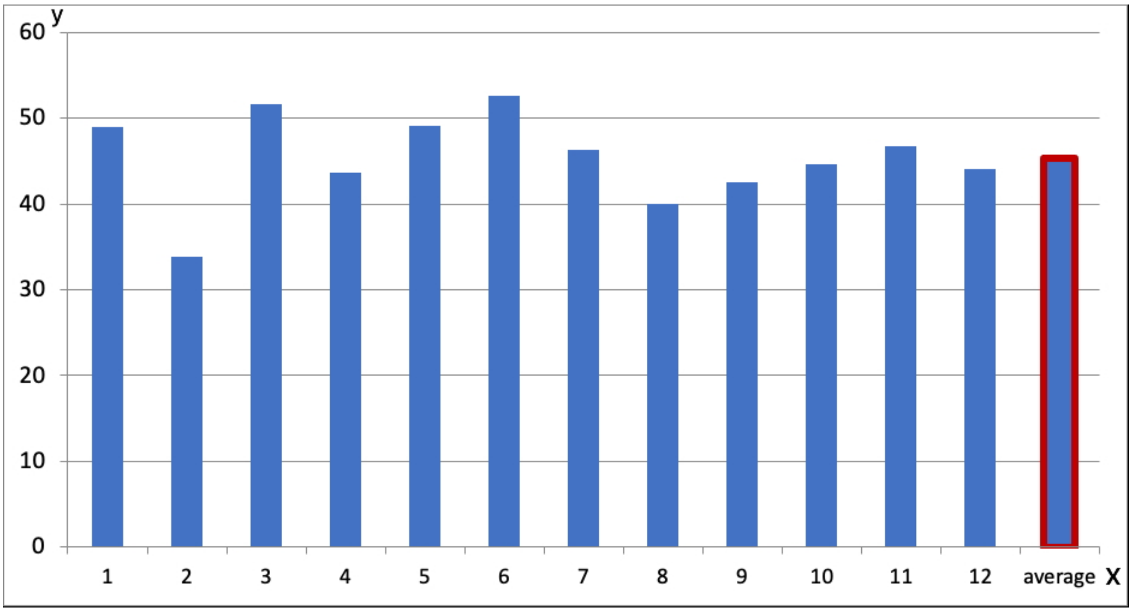

Figure 5. Clay content (%) in the soil of the Almaty district

The clay content in the soil structure from 11 sampling points in the Saryarka district averaged 42.6%, indicating heavy clay soil. Medium and light clay soil structures were observed at five points within the district, specifically points 3, 4, 5, 6, and 7. Light clay soil structure was found at points 8 to 11 (Table 4, Figure 6). Thus, in the Saryarka district, three types of granulometric soil composition - light clay, medium clay, and heavy clay - were all identified.

Table 4. Granulometric composition (%) of soil in the Saryarka district (2023) (mg/kg)

№	Coordinates N, E	1-0.5	0.5-0.25	0.25-0.1	0.1-0.05	0.05-0.01	0.01-0.002	0.002-0.001	Less than 0.001
1	N 51.185664, E 71.405463	0.8912	1.527	1.1134	38.2412	12.4681	13.2811	3.1851	29.2929
2	N 51.185385, E 71.405608	0.7215	2.2648	1.964	23.4802	21.5713	18.2047	5.8219	25.9716
3	N 51.185471, E 71.406088	0.6134	1.8215	2.1806	42.3719	16.4816	18.3029	4.0918	14.1363

4	N 51.182337, E 71.412008	0.8124	2.4917	2.631	51.4972	11.5742	19.0826	5.1872	6.7237
5	N 51.182546, E 71.412972	0.6218	1.3285	2.3849	48.2134	10.5481	15.4219	6.1804	15.301
6	N 51.182879, E 71.413128	0.5008	2.6482	2.9784	51.5403	15.6417	5.6794	7.8118	13.1994
7	N 51.188998, E 71.421163	0.6781	2.1306	1.8219	46.2781	10.492	8.9127	7.6231	22.0635
8	N 51.188015, E 71.421426	0.8215	2.0315	1.9127	34.067	10.2415	12.1716	6.1875	32.5667
9	N 51.187327, E 71.421392	0.7294	1.8942	1.7416	31.4975	15.3491	16.4972	6.1875	26.1035
10	N 51.187618, E 71.448427	0.8213	1.1892	1.1875	34.1628	12.3749	13.2719	3.1852	33.8072
11	N 51.193255, E 71.442090	0.5218	2.2791	2.2164	31.2908	10.2846	18.2461	6.2719	28.8893

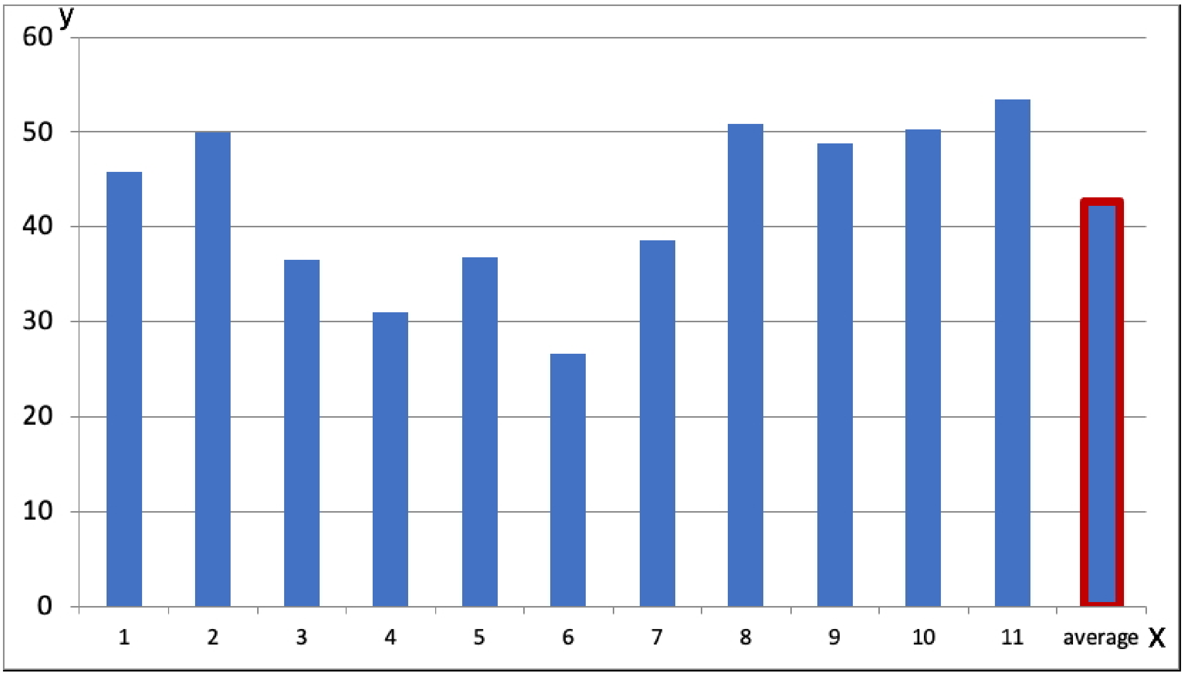

Figure 6. Clay content (%) in the soil of the Saryarka district

Soil samples were taken from 13 points to determine the granulometric composition of the soil in the Nura district. The average clay content of the district's soil was 45.4%, indicating heavy clay. Out of the 13 studies conducted on the soil in the Nura district, 11 showed a heavy clay structure.

Table 5. Granulometric composition (%) of soil in the Nura district (2023) (mg/kg)

№	**Coordinates N, E**	**Physical clay content, %**							
		1-0.5	**0.5-0.25**	**0.25-0.1**	**0.1-0.05**	**0.05-0.01**	**0.01-0.002**	**0.002-0.001**	**Less than 0.001**
1	N 51.118287, E 71.426843	0.875	2.3414	2.7191	34.2711	18.0492	7.121	7.0716	27.5516
2	N 51.109091, E 71.413948	0.7215	2.7171	2.1821	33.1471	13.4179	14.6749	6.8775	26.2619

3	N 51.108296, E 71.419763	0.8614	2.924	2.1476	30.9175	12.9171	12.7942	6.8975	30.5407
4	N 51.103654, E 71.412174	0.8953	2.8216	2.5146	32.1472	13.4481	12.9711	6.9752	28.2269
5	N 51.102852, E 71.418495	0.8198	2.0819	2.1814	33.2934	12.8571	17.4167	6.7259	24.6238
6	N 51.092000, E 71.417887	0.7108	2.9432	2.7814	37.5374	12.6237	8.941	6.1718	28.2907
7	N 51.084276, E 71.413921	0.7821	2.3426	2.2579	34.7281	12.4912	8.978	8.6491	29.771
8	N 51.076977, E 71.422716	0.8548	2.9217	2.5173	33.8267	13.4954	14.7316	6.1875	25.465
9	N 51.105531, E 71.452591	0.9414	3.1927	2.196	32.4514	16.4913	15.9172	6.1594	22.6506
10	N 51.142460, E 71.372600	0.8146	2.5474	2.8761	34.6813	15.1745	17.7134	7.1723	19.0204
11	N 51.132627, E 71.363884	0.9718	2.7462	2.8445	35.6476	14.2482	12.4576	6.7542	24.3299
12	N 51.071519, E 71.407713	0.8279	2.8277	2.4143	34.4256	15.4488	17.8467	7.1181	19.0909
13	N 51.076626, E 71.385169	0.9824	2.7837	2.8437	31.0246	17.1372	14.9172	6.8746	23.4366

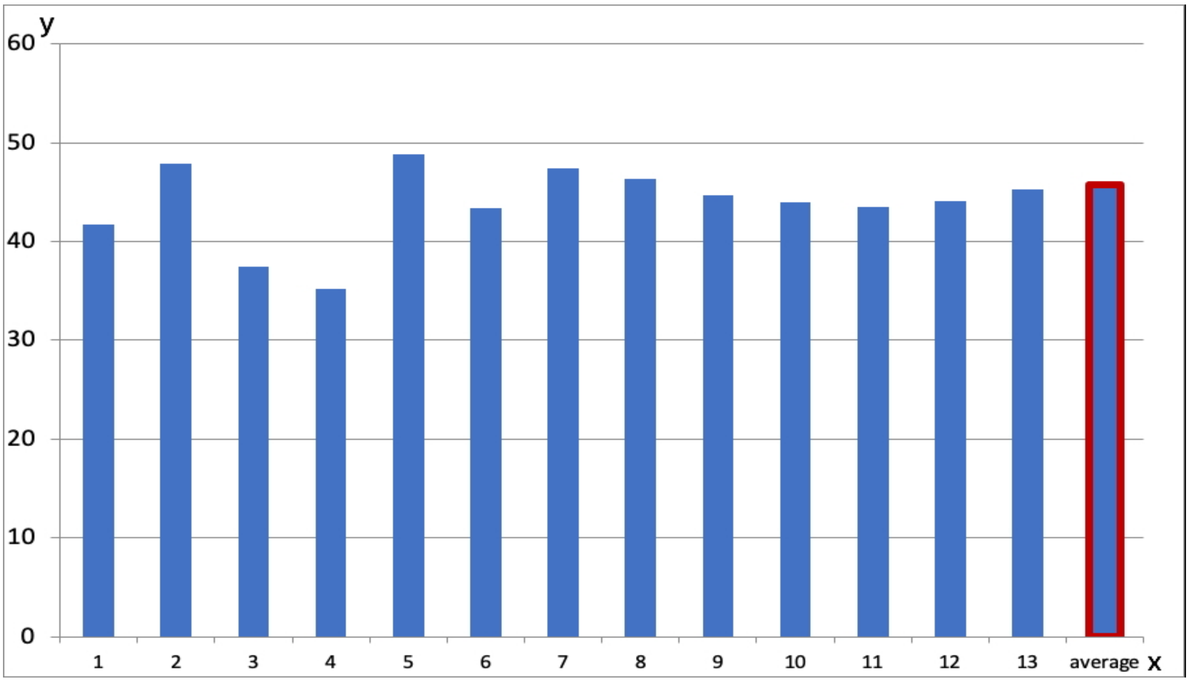

Figure 7. Clay content (%) in the soil of the Nura district

4. Discussion

The results of the 2023 study on the granulometric composition of soils across Astana city showed a high clay content in all districts. The soil samples taken from 60 points during the research confirmed that the majority of the soils have a heavy clay texture.

In the Esil district, the average clay content is 44.9%. The soil in this district predominantly has a heavy clay structure. Variations from light clay (29.3%) to heavy clay (49.9%) were observed at individual points within the district, reflecting the influence of microclimate and anthropogenic factors.

In the Baykonur district, the average clay content was 45.7%, with the highest recorded value. Some areas within this district also exhibited a light loam structure, indicating heterogeneous soil texture likely influenced by various construction, transportation, or industrial impacts.

The soil in the Almaty district has an average clay content of 45%. Although some points showed light loam structures, the overall soil texture is dominated by heavy clay.

In the Saryarka district, the average clay content is 42.6%, the lowest among the studied districts. Nevertheless, this value still classifies the soil as heavy clay. This district exhibited a diversity of granulometric compositions, including heavy, medium, and light clay textures.

The soil of the Nura district is characterized by an average clay content of 45.4%, also falling into the heavy clay category. Out of 13 samples taken, 11 showed the same structural characteristics, indicating uniformity in the soil cover of this district.

Overall, the analysis shows that the granulometric composition of Astana's soils is relatively consistent - clay content is high in all districts, with heavy clay texture predominant. These soils are agronomically favourable due to their good moisture and nutrient retention capacity. However, heavy clay soils are prone to water erosion, require more complex management, and demand special care.

The study results also indicate that urbanisation in Astana has significantly affected the soil structure. Especially in the city centre, urban soils (urbanozems) contain anthropogenic inclusions, construction debris, and dust sediments. These factors can disrupt the natural soil structure, which calls for enhanced monitoring and restoration efforts to preserve the ecological condition of the soils.

The obtained data are consistent with the results found in Berlin, where clayey and heavy loamy soils prevail, increasing their ability to accumulate pollutants (Lehmann & Stahr, 2007; Müller et al., 2021).

5. Conclusion

The majority of the granulometric composition of Astana city's soil is heavy clay. The average clay content in the soils of Astana's districts is as follows: Esil district – 44.9%, Baykonur district – 45.7%, Almaty district – 45%, Saryarka district – 42.6%, and Nura district – 45.4%. Across the districts of Astana, the average clay percentage ranges between 42.6% and 45.7%, all falling within the heavy clay category. The highest clay content was recorded in Baykonur district (45.7%), while the lowest was in Saryarka district (42.6%). Overall, the granulometric composition of soils in all districts exhibits similar characteristics.

Clay soils are rich in various nutrients, have high water and air permeability, and are easy to cultivate. Such soils are suitable for gardening and growing green spaces. The research results concluded that there is no need to improve the clay soils of this structure, only to maintain their fertility. However, it is recommended to protect the soil from negative factors that can adversely affect it. These factors include drought, soil erosion, natural disasters, industrial emissions, exhaust gases, agricultural chemicals, and other anthropogenic impacts.

This research expands theoretical understanding of urban soil granulometric patterns under anthropogenic pressure. The findings provide practical implications for urban soil management, ecological zoning, and city planning. Identifying the dominance of heavy clay soils enables targeted interventions to enhance green infrastructure, reduce erosion, and mitigate pollution risks in Astana.

6. Supplementary Materials Not applicable.

7. Author Contributions

Conceptualization, T.T.O. and A.Z.; methodology, A.Z.; software, A.Z.; validation, T.T.O., A.Z. and A.K.; formal analysis, A.Z.; investigation, A.Z.; resources, A.Z.; data curation, A.Z.;

writing - original draft preparation, A.K.; writing - review and editing, A.K.; visualization, A.K.; supervision, T.T.O.; project administration, T.T.O.; funding acquisition, T.T.O. All authors have read and agreed to the published version of the manuscript.

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Астана қаласы топырағының гранулометриялық құрылымы

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Андатпа. Қала топырағының ластану жағдайына баға беруде топырақтың гранулометриялық құрылымын анықтаудың маңызы өте зор. Атап айтар болсақ топырақта ластаушы заттардың таралу, су өткізгіштігі, химиялық реакциялардың жүруі мен биологиялық белсендігі топырақтың гранулометриялық құрылымына тікелей байланысты. Бұл зерттеу жұмысында Астана қаласы топырағының гранулометриялық (механикалық) құрамы зерделеніп, әртүрлі әкімшілік аудандар аумағынан жалпы саны 60 нүктеден топырақ үлгілері алынды. Зерттеу нәтижелері бойынша барлық аудандарда ауыр саздақты топырақ түрі басым екені анықталды. Атап айтқанда, топырақ құрамындағы саз фракциясының орташа мөлшері Есіл ауданында – 44,9%, Байқоңырда – 45,7%, Алматыда – 45,0%, Сарыарқада – 42,6%, ал Нұра ауданында – 45,4% құрады. Ауыр саздақты топырақтар ылғал мен қоректік заттарды сақтау қабілетінің жоғары болуына байланысты көгалдандыру және ауыл шаруашылығы мақсаттарына тиімді болып табылады. Алайда, мұндай топырақтар эрозиялық процестерге, антропогендік ластануға және ылғал тапшылығына ұшырауға бейім. Сондықтан бұл топырақ түрлерін тиімді пайдалану барысында экологиялық қауіптерді ескеріп, қорғаныш шараларын іске асыру қажеттілігі туындайды. Зерттеу нәтижелері қаланың топырақ ресурстарын бағалауда, оларды экологиялық тұрғыда тұрақты пайдалану және мониторинг жүргізу бағытында ғылыми негіз қалыптастырады.

Түйін сөздер: топырақ, гранулометриялық құрам, топырақ құнарлылығы, урбанизация, антропогендік әсер.

Гранулометрическая структура почвы города Астаны

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Аннотация. Определение гранулометрического состава почвы имеет важное значение при оценке загрязнения городской почвы. В частности, распространение загрязняющих веществ, водопроницаемость, протекание химических реакций и биологическая активность напрямую зависят от гранулометрической структуры почвы. В данном исследовании изучен гранулометрический (механический) состав почв города Астаны, для чего были отобраны образцы почвы в 60 точках, расположенных в разных административных районах. Результаты показали, что во всех районах преобладают тяжелосуглинистые почвы. Среднее содержание глинистой фракции составило: в районе Есиль - 44,9%, в Байконуре - 45,7%, в Алматы - 45,0%, в Сарыарке - 42,6%, в Нуре - 45,4%. Благодаря высокой способности удерживать влагу и питательные вещества, тяжелосуглинистые почвы считаются благоприятными для озеленения и сельскохозяйственного использования. Однако такие почвы подвержены эрозии, антропогенному загрязнению и дефициту влаги. Поэтому при их использовании необходимо учитывать экологические риски и внедрять меры по защите. Полученные результаты служат научной основой для оценки почвенных ресурсов города, их экологически устойчивого использования и организации мониторинга.

Ключевые слова: почва, гранулометрический состав, плодородие почвы, урбанизация, антропогенное воздействие.