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ARTICLE

Results of the study of pH and organic matter in the surface soil of Ulaanbaatar

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Abstract: This work summarizes the results of a study into such important urban soil parameters as soil actual (pH) and potential acidity (pH) and soil organic matter content (SOM) in the surface soil of Ulaanbaatar. The soil pH in Ulaanbaatar is slightly alkaline, with a median pH value of 7.36 (actual acidity) and 6.93 (potential acidity), and they were found to be the highest in the industrial zone as compared to other zones in the city. The median value of organic matter content in Ulaanbaatar surface soil was 5.61%, with a high variability in the industrial (C.V.-119%) and transport (C.V.-55.34%) zones. The SOM mean value in urban soil is less than the background value in surface soil from natural area, indicating to increasing compaction and reduction of porosity of soil in urban areas. Also, organic matter content have decreased relatively to previous data, reflecting the urbanization process and such long-term processes as aerial urban fallout.

Keywords: *pH; organic matter; soil; Ulaanbaatar;*

INTRODUCTION

The study of the property of soil in urban areas is an urgent environmental task in an urban setting. Within urbanized areas, the chemical and physical properties of surface soil, such as pH and soil organic matter (SOM), can be significantly different from those in soils in a non-urban setting [1, 2].

Soil pH is an indicator of soil acidity or alkalinity, which reflects the physical and chemical properties of the quality of soil [1-3]. Extremes in acidity or alkalinity will change the available nutrients in soil and result in element imbalances in plants [1, 3].

Soil organic matter (SOM) content affects a number of soil properties and nutrient cycling [1-4]. The SOM content and its quality are considered as a key factor in the soil ability to maintain biological productivity, the quality of the environment and the ecosystem as a whole [1-4].

Therefore, studying pH and SOM and understanding their spatial variability in urban soils are important for taking knowledgeable decisions on soil management.

Our previous studies focused only on elemental determination in the surface soil of Ulaanbaatar and their multivariate and geospatial analysis [5, 6]. Such soil properties, as pH and organic matter in soils, have only been studied as appendix study [7].

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To date, there are no comprehensive studies on such key properties as acidity and alkalinity (pH) and soil organic matter (SOM) content in Ulaanbaatar's surface soil.

The aim of this study was to investigate acidity and alkalinity (pH) and soil organic matter (SOM) content in Ulaanbaatar's surface soil.

To achieve the goal, the following tasks have been set:

1. Measure the acidity and alkalinity (pH) and determine the soil organic matter (SOM) content in Ulaanbaatar's surface soil samples
2. Using statistical and geo-statistical methods, analyze laboratory data of acidity and alkalinity (pH) and of soil organic matter (SOM) content. Focus on the following, basing on statistical and geo-statistical analysis:
   a) Describe the distribution trend and dispersion of acidity and alkalinity (pH) and of soil organic matter (SOM) content;
   b) Investigate the spatial distribution trend of acidity and alkalinity (pH) and of soil organic matter (SOM) content in Ulaanbaatar's surface soil, depending on the land use category; and,
   c) Produce spatial distribution maps of pH value and SOM content.

MATERIALS AND METHODS

Soil field studies were carried out in summer 2019, on the territory of Ulaanbaatar. In accordance with the functional zones, the soil samples were divided into sub-samples (industrial, transport, residential and recreational).

Soil sampling and preparation for analysis

The sampling, storage, transportation and preparation of soil samples for chemical analysis were carried out in accordance with the set standards and methods [8-11]. Mixed soil samples were collected by the "envelope" method and an irregular sampling network and at a depth of 0 to 10 cm. A total of 90 soil samples were taken. The soil samples were dried to an air-dry state at room temperature and were manually cleaned of large inclusions, such as stones, broken glass, roots and plants; they were crushed in a ball mill (Fritsch GmbH), then homogenized by sieving through a sieve with a mesh of 74 mm, and packed in paper bags. The sampling coordinates were recorded using GPS, the sampling site was generated using the ArcGIS software, which is shown in Fig. 1.

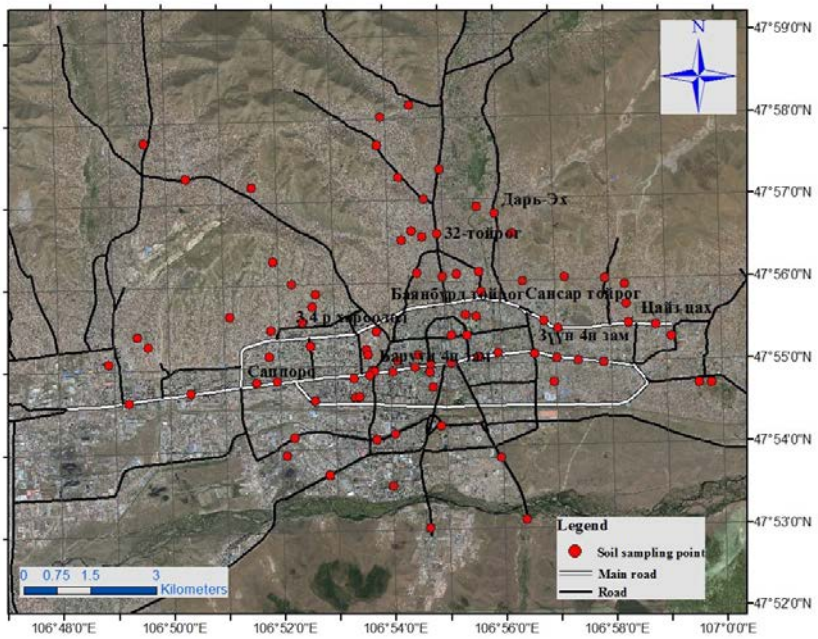

Figure 1. Sample collection scheme

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Chemical analysis

Chemical analysis was carried out in atomic spectroscopy laboratory at the Institute of Physics and Technology of the Mongolian Academy of Sciences. The soil actual-$pH_{(H2O)}$ and potential-$pH_{(KCl)}$ acidity were performed by potentiometric method using a pH meter (Hanna, Germany) in the sample after soil was extracted with water and KCl. The soil extracts was prepared by standard method, at a soil and solution ratio of 1:2.5 [12]. Soil organic matter (SOM) content was determined by loss on ignition [13].

Statistical and geo-statistical analysis

To describe the central trend and dispersion, such statistical parameters were calculated as mean, maximum, minimum, median, standard deviations, skewness, kurtosis, and coefficient of variation (CV) for each soil properties. The data distribution for normality was checked using the Shapiro-Wilk test (S–W, $p<0.05$). When the statistical distribution was not normal, the variables were transformed by the Box-Cox method. The differences in the mean values for pH and organic matter content (SOM) between the different land-use types were determined by the non-parametric Kruskal-Wallis (K-W) and median (ANOVA) tests.

All statistical analyzes were performed using software Statistica -13 for Windows.

The distribution map of actual-$pH_{(H2O)}$ and potential-$pH_{(KCl)}$ acidity and organic matter (SOM) content in Ulaanbaatar's surface soil was constructed by the kringing interpolation method using software ArcGIS-10.2 for Windows.

RESULTS AND DISCUSSION

Descriptive statistics of pH and organic matter in Ulaanbaatar surface soil

Table 1 presents the descriptive statistics of actual-$pH_{(H2O)}$ and potential-$pH_{(KCl)}$ acidity and organic matter (SOM) content in surface soil, including minimum, maximum, median, mean, geometric means, coefficients of variation, skewness and kurtosis at 95% confidence intervals. Also, Table 1 shows Shapiro-Wilks normality test for checking the distribution in a parameter data set. Additionally, the distribution trend of acidity (pH) and organic matter (SOM) content in Ulaanbaatar's surface soil are shown in histograms in Figure 2.

Table1. Descriptive statistics of soil pH and organic matter (SOM) in Ulaanbaatar's surface soil

Parameter	BG [7]	Statistics of set of obtained values of parameters					Statistics of data spread		Coefficients, describing data		
		μ	M	GM	mini-mum valluенач	max. valuенач	σ	V	Raw data		
									S	K	S-W, $p<0.05$
SOM	7.95	6.48	5.61	5.48	0.04	37.73	4.47	68	4.42	28.12	0.00
$pH_{(H2O)}$	6.61	7.35	7.36	7.34	6.00	8.56	0.46	6	-0.54	1.22	0.02
$pH_{(KCl)}$	-	6.87	6.93	6.86	5.64	8.00	0.38	5	-0.84	2.40	0.00

For Ulaanbaatar surface soil samples, the values of asymmetry (S) and kurtosis (K) of soil actual-$pH_{(H2O)}$ and potential-$pH_{(KCl)}$ acidity are less than 1 and 3 respectively, indicating a normal pH distribution and this is confirmed as is shown in the histogram (see Fig. 2). The asymmetry (S) of organic matter in Ulaanbaatar's surface soil is greater than one and shows right-sided asymmetry, reflecting the increased content of organic matter in some places due to urbanization. The high kurtosis value can also be explained by the fact that the maximum number of samples shows relatively lower values.

Organic matter content in Ulaanbaatar's soil also showed a high standard deviation

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degree, reflecting its uneven distribution as shown in the histogram (see Fig.2) and indicating large influence of anthropogenic factors on SOM content [3,14].

The Shapiro - Wilks test (S – W, $p < 0.05$) demonstrated that soil pH is evenly distributed, but on the contrary, the soil organic matter (SOM) is not evenly distributed.

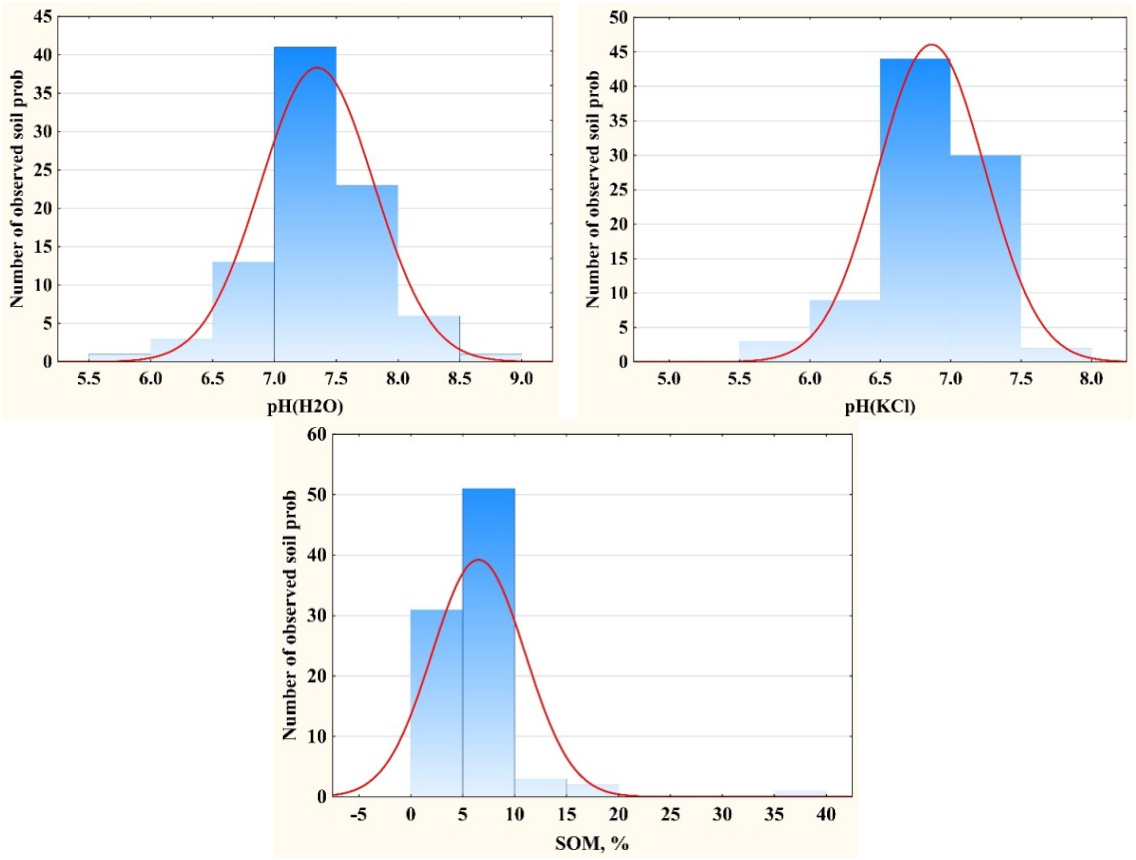

Figure 2. Histograms of pH and SOM in Ulaanbaatar's surface soil

Spatial distribution of acidity and alkalinity (pH) and soil organic matter content (SOM) in Ulaanbaatar soil

Spatial distribution of soil actual-$pH_{(H2O)}$ and potential-$pH_{(KCl)}$ acidity and organic matter content (SOM) in surface soil from different land-use categories such as A-Industrial (5); B-Residential administrative (16); C-Multi-storey housing (9); D-Yurt zone (33); E-Transport zone (23); F-Recreation zone (2) are shown in Table 2 and in Figure 3.

The difference of mean values for pH and SOM in surface soil from different land use types was determined by the nonparametric Kruskal-Wallis and ANOVA tests and the results are shown in Table 2. Also, in Table 3 are summarized the descriptive statistics of soil pH and organic matter (SOM) in surface soil from different land-use categories.

As summarized in the Table 3, no significant difference was found in the mean value of soil actual-$pH_{(H2O)}$ and potential-$pH_{(KCl)}$ acidity and soil organic matter (SOM) content in Ulaanbaatar's surface soil. As shown in Table 1 and in Fig. 3, the soil actual acidity-$pH_{(H2O)}$ in Ulaanbaatar's surface soil varied from slightly acidic (6.00) to alkaline (8.56) with an average of 7.36 (slightly alkaline), which is higher than the background value [7] of the $pH_{(H2O)}$ and is comparable to the previous result [7].

The lowest value of actual acidity - $pH_{(H2O)}$ was found in surface soil from the recreational zone with an average 7.05 (neutral) and ranging from neutral (6.86) to slightly alkaline (7.24). The highest value of actual acidity -$pH_{(H2O)}$ was found in surface soil from the industrial zone with an average 7.74 (alkaline) and ranging from slightly acidic (6.02) to alkaline (8.07) (Table 2 and Fig. 3).

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Table 2. Descriptive statistics of soil pH and organic matter (SOM) in surface soil from different land-use categories

Parameter	Statistics of set of obtained values of parameters					Statistics of data spread		Coefficients, describing data		
	μ	M	GM	min. value	max. value	σ	V	Raw data		
								S	K	W
A-Industrial (5)										
SOM	12.54	4.22	7.27	2.33	37.73	14.92	119.00	1.71	2.70	0.04
pH H2O	7.43	7.74	7.39	6.02	8.07	0.83	11.19	-1.74	3.09	0.10
pH KCl	6.77	6.98	6.74	5.65	7.30	0.68	10.04	-1.51	2.15	0.16
B-Residential administrative (16)										
SOM	6.65	6.79	5.88	1.83	12.93	3.11	46.81	0.24	-0.65	0.69
pH H2O	7.34	7.26	7.34	6.95	8.03	0.33	4.50	1.06	0.52	0.05
pH KCl	6.81	6.75	6.80	6.34	7.59	0.36	5.28	0.75	-0.03	0.30
C-Multi-storey housing (9)										
SOM	5.20	4.31	4.84	2.93	7.97	2.03	39.12	0.26	-1.94	0.13
pH H2O	7.59	7.51	7.57	7.02	8.56	0.49	6.40	1.02	0.82	0.46
pH KCl	7.09	6.99	7.08	6.65	8.00	0.40	5.61	1.66	3.44	0.09
D-Yurt zone (33)										
SOM	6.37	5.88	6.02	2.95	18.31	2.59	40.72	3.16	14.04	0.00
pH H2O	7.27	7.28	7.25	6.00	8.06	0.52	7.19	-0.66	0.20	0.12
pH KCl	6.92	7.05	6.91	5.64	7.36	0.39	5.57	-2.09	4.76	0.00
E-Transport zone (23)										
SOM	5.60	4.56	4.35	0.04	16.62	3.10	55.34	2.07	7.03	0.00
pH H2O	7.37	7.40	7.37	6.62	7.88	0.32	4.29	-0.57	0.10	0.70
pH KCl	6.79	6.89	6.79	6.07	7.08	0.27	3.98	-1.27	1.13	0.01
F-Recreational zone (2)										
SOM	9.8	9.8	9.6	7.9	11.6	2.6	26.8	-	-	-
pH H2O	7.1	7.1	7.0	6.9	7.2	0.3	3.8	-	-	-
pH KCl	6.4	6.4	6.4	6.3	6.6	0.3	4.1	-	-	-

Potential acidity - $pH_{(KCl)}$ in Ulaanbaatar's surface soil varied from slightly acidic (5.64) to alkaline (8.00) with an average of 6.93 (neutral). The distribution trend of the potential acidity - $pH_{(KCl)}$ in the surface soil from the yurt area of the residential zone is the same as $pH_{(H2O)}$, however, outliers and extremes are observed. A slightly acidic, neutral or slightly alkaline soil acidity in Ulaanbaatar's surface soil is most favorable for plant growth, the vital activity of microorganisms and directions of soil biochemical processes.

Table 3. Results of Kruskal-Wallis (K-W) and median (ANOVA) test

Parameter	K-W test		Median test	
	H	p	χ2	p
SOM	7.63	**0.18**	7.57	**0.18**
pH(H_2O)	5.21	**0.39**	7.62	**0.18**
pH(KCl)	11.74	0.04	10.37	**0.07**

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As a key component of soil, organic matter directly affects the physical-chemical properties of soil, reflecting the nutrients and pollutants state in the soil as heavy metals and organic toxicants through adsorption and complexation [3, 4, 14].The accumulation of organic matter is facilitated by the intake of aerial organic pollutants, high carbon dioxide content in the air, the mineralization of plant residues under the influence of pollution and increased productivity of vegetation due to increased temperature and care for green areas: covering large areas in cities, peat application, irrigation and drainage of soils [3, 4].

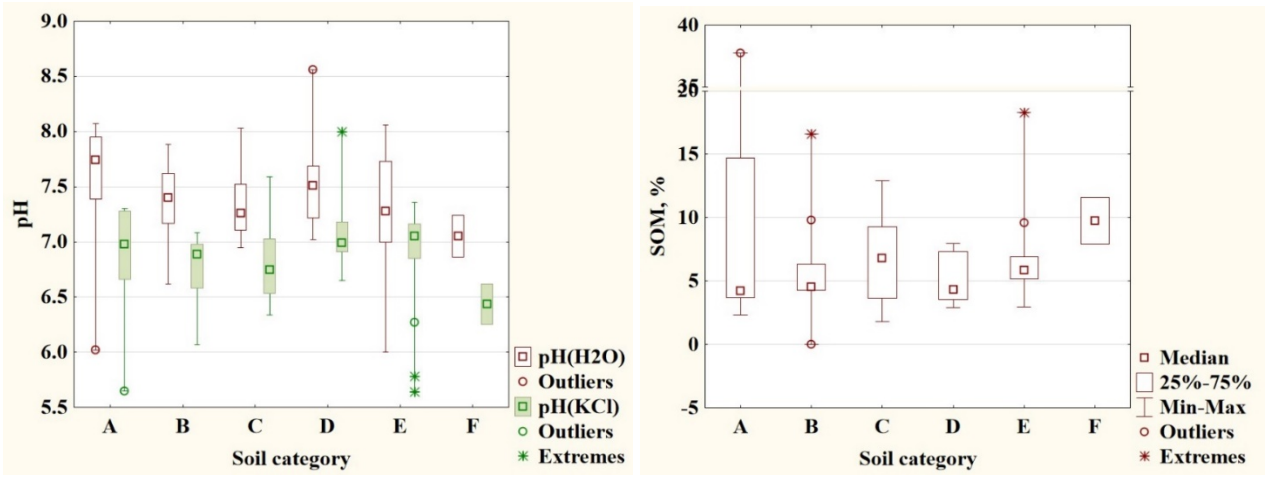

Figure 3. Spatial distribution of acidity and alkalinity (pH) and organic matter content (SOM) in surface soil from different land-use categories (A-Industrial; B-Residential administrative; C-Multi-storey housing; D-Yurt; E-Transport; F-Recreational

In Ulaanbaatar's surface soil, organic matter content varied significantly and varied from 0.04 to 37.73% with mean values of 5.61%, which is less than the background value in surface soil from natural area, where the content of organic matter was 7.97% [7], indicating soil compaction and reduction of porosity of soil in urban area [3].

A decrease in organic matter content value in Ulaanbaatar 'surface soil was found as compared with the previous data [7], reflecting rapid urbanization and the impact of long-term processes as aerial urban fallout [3].

The low level and high variability of SOM is mainly due to the influence of soil land-use types as industry (C.V.-119 %) and transport (C.V.- 55.34 %). According to the median value, the minimum value (4.22%) of the organic matter content was found in the surface soil from the industrial zone with a wide range from 2.33 to 37.73%, and the maximum value (9.76%) of the organic matter content was found in the surface soil from the recreational zone with a smaller range from 7.91 to 11.61%.

Spatial distribution maps of pH and SOM in Ulaanbaatar surface soil

Spatial distribution maps of pH and SOM in Ulaanbaatar's surface soil is shown in Figure 4.

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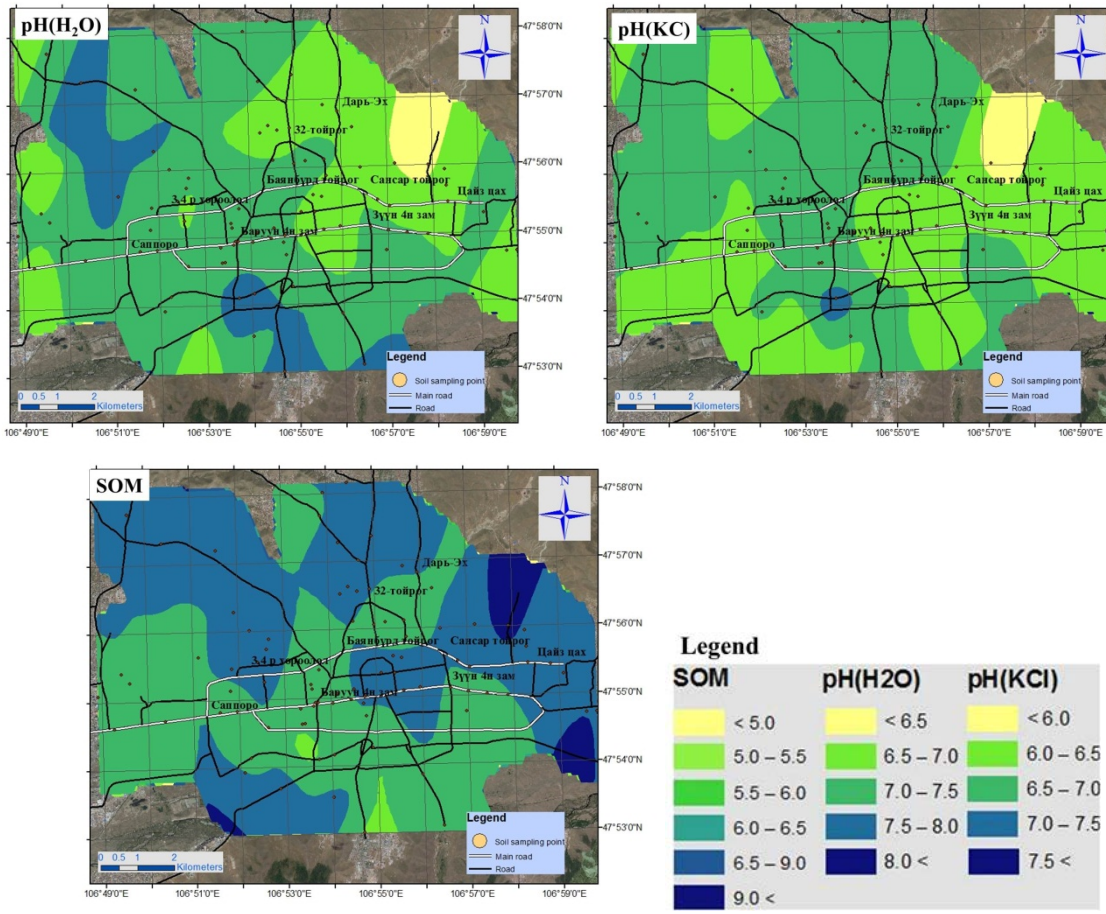

Figure 4. Spatial distribution maps of pH and SOM in Ulaanbaatar's surface soil

As shown in Figure 4, geographical distribution of actual –$pH_{(H2O)}$ and potential – $pH_{(KCl)}$ acidity and soil organic matter content (SOM) on Ulaanbaatar's territory can be attributed to the landscape of the city area and the land-use type [1-4, 13]. The trend of geographical distribution of acidity and soil organic matter content (SOM) is different.

Greatest organic matter has been registered in the northeastern, eastern and northwest parts, which are primarily yurt residential area, where illegal dumping occurs and which are close to the industrial zone of the city. Therefore, the accumulation source of organic matter in Ulaanbaatar's surface soil are household and industrial wastes, containing carbonized waste and soot of coal particles. Also, the greatest soil organic matter is revealed in the city center (along central transport highways and in the vicinity of bus terminal).

CONCLUSIONS

Within urbanized areas, acidity pH and organic matter (SOM) of soil can be significantly different from non-urban soils. Soil pH and SOM reflect the physical and chemical properties of soil quality and they impact a number of soil properties and nutrient cycling.

The distribution and dispersion of acidity (pH) and organic matter content (SOM) in Ulaanbaatar's surface soil, as well as the trends in their distribution, depending on the land use category, were studied. Additionally, mapping of spatial distribution of pH and SOM content were performed.

In Ulaanbaatar's surface soil, the distribution of pH is normal, however, on the contrary, soil organic matter (SOM) content distribution is not even and normal.

- The soil pH in Ulaanbaatar city is slight alkaline, with a median value pH of 7.36 (actual acidity) and 6.93 (potential acidity), which was found to be the highest in the industrial zone as compared to other zones.

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- The median value of organic matter content in Ulaanbaatar's surface soil was 5.61%, with a high variability in industrial (C.V.-119 %) and transport (C.V.-55.34%) zones. The SOM mean value in urban soil was less than the background value in surface soil from natural area, indicating to increased compaction and reduction of porosity of soil in urban area. Also, organic matter content decreased relatively to previous data, reflecting the urbanization process and such long-term processes as aerial urban fallout.

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