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Characteristics of soil-peat-rubble mixtures by mercury intrusion porosimetry**

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A b s t r a c t. The effect of cyclic changes of temperature and the addition of organic matter on pore properties of model urban soil was investigated. Mixtures composed from a loessial soil with 10–50% w/w of rubble and 6% w/w of peat were studied. The mixtures were moistend to 25% of their field water capacity and subjected to cyclic changes of temperature. Before and after the cycles granulometric composition, organic matter content and mercury intrusion porosimetry studies were performed. Samples of the model urban soil before freezing-thawing cycles had lower values of the structural parameters than after cyclic changing of temperature. Those hanging concerned first of all the total cumulative volume and pore size distributions. The observed changes depended on the properties of added building materials, which changed to a greater extent under the cycles' change of temperature than the soils themselves.

K e y w o r d s: urban soil, mercury intrusion porosimetry, granulometric composition, organic matter, rubble

INTRODUCTION

Structure is one of the most of dynamic elements of the soil environment. It determines the physical, chemical and biological properties of soils [12,14]. Many studies have pointed out the important role of organic matter, pH, mineralogical composition and many others in the formation and stabilization of soil aggregates [4,13,15]. Organic matter (peats) is frequently added to city-soils to improve their fertility. The structural properties of urban soils in the cities are particularly affected by building activity. Building materials inserted into the soil horizon markedly alter the structure of these soils, first of all in superficial layers. After the end of building activities, rubble is usually left on the building site. This rubble contains large or small pieces of brick, concrete, foam concrete and mortar. The role of these components of urban soils on soil structure is less well understood.

Humidity and temperature are the main elements of the climate that determines the physicochemistry and mechanical properties of soils. Low temperature and capillary water destroy soil aggregates and increase specific surfaces of soils [6,11]. Freezing and thawing of water cause mixing of soils layers within all horizons [1,3,19]. All these effects significantly influence soil structure.

The soil structure can be characterised by its porosity [5,8–10,18]. Many soil properties, e.g., transport of water and gases in soil or penetration by roots, depend on soil pore volume, radius and bulk density.

The aim of this work was to study the influence of cyclic changes of temperature and the addition of organic matter on physicochemical properties of model urban soils obtained by enrichment of a soil with various doses of a rubble.

MATERIALS AND METHODS

Artificial urban soils composed by mixing loessial soil (Elizówka-Lublin) with various amounts of a rubble containing equal w/w proportions of 1mm sieved materials: brick, concrete, foam concrete and mortar were studied. Soil material from 0–20 and 20–40 cm depth (A and B horizons) was used. The amount of the rubble in the mixtures was 10, 20, 30, 40 and 50 w/w%.

The mixtures were moistened to 25% of their moisture and subjected to six cyclic changes of temperature. Each cycle consisted of a one-week treatment at 30°C following by one week at minus 35°C.

Next the samples were subjected to porosimetric (Carlo Erba Mercury Porosimeter 2000) and granulometry (areometric method) analysis. Before porosimetric measurements,

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the samples were oven-dried at 105°C and then outgassed in a vacuum to remove physically adsorbed water. The range of mercury pressure applied allowed us to study pores with equivalent radii ranging from 3.7 to 7500 nm. The pore radii were calculated using the Washburn equation [7,16].

The surface tension and the contact angle of mercury were assumed to be 48.9 J m^{-2} and 141.3 , respectively. Using cylindrical pore model bulk density the surface area, average pore radius and total porosity were calculated [7,17].

Granulometic analysis was performed using the aerometric method of Bouyoucos modified by Cassagrande and Pruszyński. For the latter analysis, the soil samples were dispersed using a 0.5% Calgon (sodium metahexaphosphate) water solution.

The content of organic matter in the samples was measured by dichromate oxidation using Tyurin method [16].

RESULTS AND DISCUSSION

The results are shown in Tables 1–3 and Figs 1–3. Addition of a rubble altered soil granulometric composition is shown in Table 1. The fraction of coarse >1mm particles (sand fraction) increased which caused a decrease in finer particles content, simply by their dilution. This indicates that the soil after rubble addition can become more easily permeable for water and over dried. However, with the addition of the peat and after wetting-drying cycles the fractions of silt and clay increased, counteracting the above changes.

Figures 1 and 2 show examples of the pore volume versus intrusion pressure for the soil, peat and rubble, before and after cyclic changes in temperature. The rubble material, as well as the peat, had a very high porosity. Therefore their addition to the soil caused the overall increase in the pore volume in the whole pore range, which is illustrated in Fig. 3. Cyclic changes of temperature altered the porosity of the samples. These changes were similar in mixtures containing soil from both A and B horizons, therefore only the curves for the A horizon are depicted.

As seen in Table 2, the pore volumes of the samples before cyclic changes of temperature ranged between 101.16 mm^3 g^{-1} (soil, A horizon) and 175.21 mm^3 g^{-1}, (soil

T a b l e 1. Granulometric composition of model urban soils before and after cyclic changes of temperature

Rubble (%)	A horizon			B horizon		
	Sand	Silt	Clay	Sand	Silt	Clay
	(%)					
Initial soil-rubble mixtures						
0	5	59	36	6	53	41
10	18	48	34	41	36	23
20	23	46	31	34	46	20
30	33	43	24	36	31	24
40	35	40	25	38	38	24
50	45	37	18	45	34	21
Initial soil-rubble mixtures after addition of peat						
0	26	56	18	26	56	18
10	38	39	23	25	43	32
20	32	41	27	29	45	26
30	32	38	30	32	44	24
40	38	38	24	39	43	18
50	39	42	19	40	40	20
Soil-peat-rubble mixtures after cyclic changing of temperature						
0	11	40	49	19	46	35
10	15	52	33	22	41	37
20	48	37	15	24	47	29
30	28	44	28	32	46	22
40	35	42	23	41	45	14
50	24	50	26	48	37	15

Sand (1–0.1 mm), Silt (0.1–0.02 mm), and Clay (<0.02 mm).

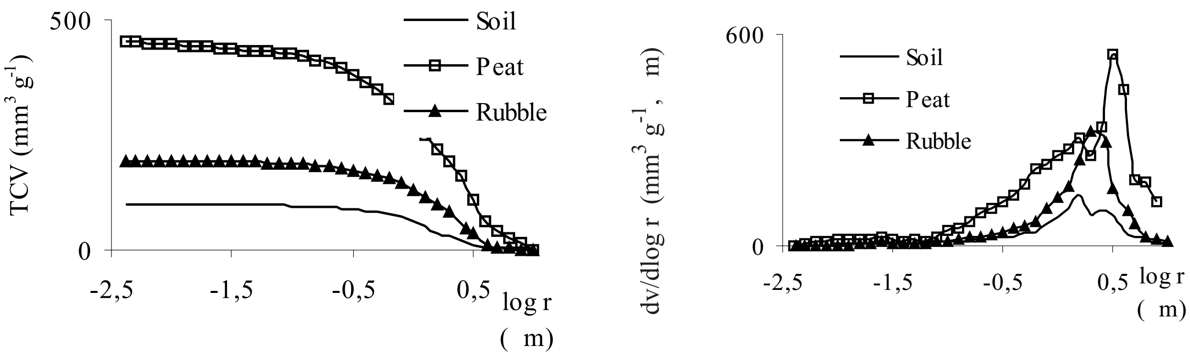

Fig. 1. Exemplary pore size distribution functions of model urban soils before cyclic changes of temperature.

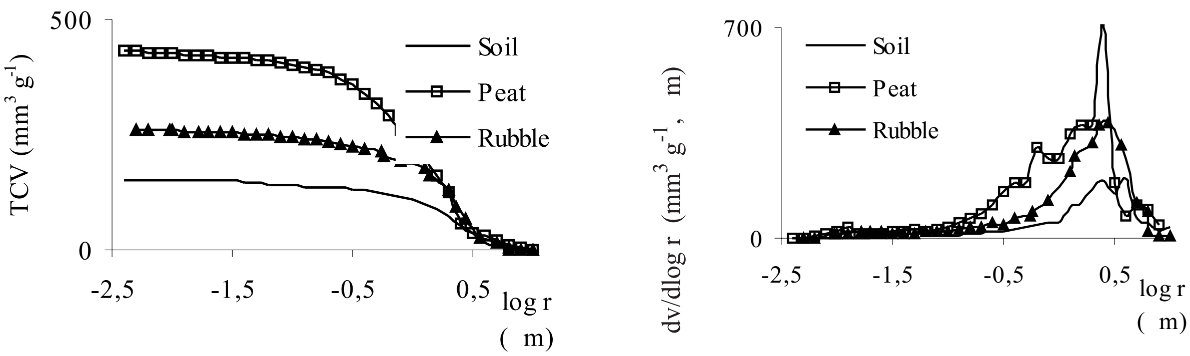

Fig. 2. Exemplary pore size distribution functions of model urban soils after cyclic changes of temperature.

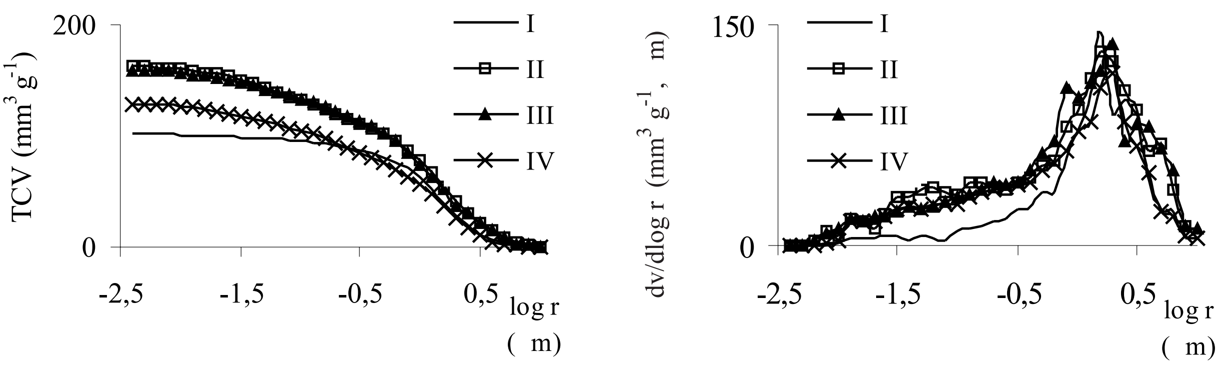

Fig. 3. Exemplary pore size distribution functions of model urban soils as affected by cyclic changes of temperature. Abbreviations: I – initial A horizon of soil; II– soil + 50% rubble; III – soil + 50% rubble + peat; IV– mixture III after cyclic changes of temperature.

T a b l e 2. Pore properties of model urban soil after and before cyclic changes of temperature

Rubble (%)	A horizon				B horizon			
	Total cum. volume (mm^3 g^{-1})	Total porosity (%)	Bulk density (g cm^{-3})	Aver. pore radius (nm)	Total cum. volume (mm^3 g^{-1})	Total porosity (%)	Bulk density (g cm^{-3})	Aver. pore radius (nm)
Initial soil-rubble mixtures								
0	101.16	18.60	1.84	1249.6	121.44	23.19	1.91	3072.0
10	101.16	18.61	1.84	1579.0	116.00	24.46	1.85	1981.1
20	100.98	17.06	1.69	1249.6	113.76	21.27	1.87	1931.7
30	161.08	29.96	1.86	1580.4	123.83	23.55	1.90	2487.5
40	122.30	22.13	1.81	1250.2	119.29	22.30	1.87	3075.1
50	161.96	26.88	1.66	1249.9	118.84	21.03	1.77	1250.2
Initial soil-rubble mixtures after addition of peat								
0	159.79	28.28	1.77	1249.8	131.70	22.38	1.70	1249.9
10	131.87	24.13	1.83	994.2	172.39	28.44	1.65	1579.7
20	109.19	21.51	1.97	1249.2	145.14	25.25	1.74	1579.5
30	117.23	21.80	1.86	1547.2	127.63	22.46	1.76	1249.8
40	131.24	24.27	1.85	2408.4	125.32	21.68	1.73	1249.4
50	159.32	27.88	1.75	1578.4	175.21	30.48	1.74	1933.0
Soil-peat-rubble mixtures after cyclic changing of temperature								
0	130.12	23.29	1.79	1980.7	89.87	17.25	1.92	1979.4
10	86.77	16.74	1.93	1978.8	114.40	21.62	1.89	1249.7
20	121.39	22.82	1.88	2485.1	98.13	18.64	1.90	1578.5
30	96.79	18.09	1.87	1978.6	144.07	26.51	1.80	1980.5
40	115.07	21.63	1.88	1979.1	121.34	21.59	1.84	1979.1
50	98.40	18.30	1.86	1978.6	112.72	20.28	1.78	1980.0

T a b l e 3. Organic matter content (%) in model urban soils before and after cyclic changes of temperature

Rubble (%)	A horizon			B horizon		
	I	II	III	I	II	III
0	0.30	4.40	3.56	0.33	4.45	4.43
10	0.29	4.00	3.69	0.23	4.05	3.24
20	0.30	3.90	3.78	0.27	4.20	3.31
30	0.32	3.60	3.81	0.29	4.55	4.02
40	0.34	4.30	3.32	0.30	3.95	3.85
50	0.35	4.10	3.28	0.34	4.10	3.94

I – Initial soil-rubble mixtures, II – Initial soil-rubble mixtures after addition of peat, III – Soil-peat-rubble mixtures after cyclic changing of temperature.

B horizon – 50% of rubble). After cyclic changes of temperature these values generally decreased ranging from 86.77 mm^3 g^{-1} (soil A horizon – 10% of rubble) to 144.07 mm^3 g^{-1} (soil B horizon – 30% of rubble). The total porosity of the materials before applying temperature cycles ranged between 18.6 and 30.48% and after the cycles these values decreased ranging between 16.74 and 26.51% (the same soils as above). Most probably large aggregates were damaged due to the temperature and humidity effect, which lead to the decrease in overall porosity and increase of fractions of smaller pores.

In the soil and the model mixtures which were not subjected to cyclic changes of temperature, the radius of dominant pores was around 1 to 3 mm. After these cycles a slight shift in dominant pore radii towards larger sizes (1.5–3 mm) occurred. These changes in pore size distribution indicates a rearrangement of the samples stucture. Simultaneously, the effect of the temperature changes may involve dehydratation of soil colloids which can lead to stronger aggregation and an accompanied increase of large and medium-size pores which, despite the drop in pore volumes, may lead to some shift in dominant pore radii.

The content of organic matter after addition of the peat increased from 0.35 to 4%, however after each temperature cycle this subsequently decreased (Table 3). This might be due to the intensive mineralization of organic matter in well aerated samples. This unfavourable process may be connected with laboratory conditions. In natural environments the organic matter decrease is frequently restored by turnover of residues of living organisms.

CONCLUSIONS

As a result of cyclic changes of temperature a subsequent decrease in the content of organic matter was observed in model urban soils. Additions of peat and rubble to the soil caused an increase of the total cumulative volume of pores in all pore size range accompanied by an increase of the relative amounts of medium and large pores. Freezing-thawing cycles decreased pore volumes of the soil-rubble-peat mixtures and caused a further increase of the dominant pore range.

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