Acta Agrophysica, 2012, 19(4), 703-712

EFFECT OF THE PRESENCE OF BUILDING MATERIALS ON THE BUFFER PROPERTIES OF SOIL

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Abstract. A study was made on the effect of the presence of rubble of building materials on the buffer capacity of loess soil (Typic Entrochrept acc. to FAO). Ground building materials: brick, concrete, foam concrete and mortar were added to the soil. Additionally, identical mixtures were prepared, with an addition of 6% of peat as reclamation material for the model mixtures. The prepared mixtures were subjected to thermal stress. They were frozen to –20°C, then the samples were transferred to a temperature of 30°C, all the time maintaining constant moisture at the level of 25% by weight, that is in the moisture range between the field water capacity and the wilting point for the loess soil. In the course of the study a significant impact of the building materials on the loess soil buffer capacity was observed. They varied with relation to the type of building material added, the time of thermal stress, and the additional presence of peat. It was found that the presence of building materials increased the buffering capacity of the soil in relation to substances of acidic nature. The presence of peat caused a reversal of this process. The ability of peat to remediate a soil degraded with building materials was also confirmed in the course of the study of the effect of thermal stress on the buffer capacity of the soil and its mixtures. With extension of the time of thermal stress, there was a decrease in the differences in buffer capacity between the particular mixtures and the soil.

Keywords: buffer capacity, construction materials, loess soil

INTRODUCTION

In soil science literature more and more attention is devoted to the properties of urbisols. The research undertaken is focused primarily on the degradation of urban soils caused by human activity. In cities there are areas that have not been changed by man, and areas that have been totally degraded, together with the whole soil profile (Huinik 1998, Uwe *et al*. 1998). In urban areas studies have been conducted on the content and mobility of heavy metals in the soil, plants, municipal solid wastes and sewage (Boisson *et al*. 1999, Richards *et al.* 2000, Wilcke and Kaupenjohann 2006). Also green areas of cities have been studied, such as parks, lawns, cemeteries or allotments, as well as other areas (Czekała *et al*. 1998; Wilcke *et al.* 2003, Czarnecka and Sugier, 2006, Sugier and Czar-necka 2006), primarily in the aspect of heavy metals content.

Under natural conditions, soils are in a state of relative equilibrium that can undergo changes (favourable as well as unfavourable) under the effect of various factors. Within limits, soil has an ability to resist noxious effects, which is related with e.g. its buffer capacity (Huang 2009, Filipek and Badora 1999). The maintenance of equilibrium in soil has an effect on reclamation operations that may cause a slow-down of the process of decontamination of soil (Kowalik 2001). Contaminated soil transfers noxious components to plants and then on to their consumers, or causes secondary contamination of other elements of the environment. For this reason proper estimation of the status of soil contamination becomes an extremely important issue. Chemical substances affect the reaction of soil, its salinity, and also disturb the balance in the cycle of micro- and macroelements in soil (Mario 2009).

Among the most dangerous pollutants of soils are heavy metals and their compounds that have a toxic effect on the entire environment. Their presence in the soil environment is a fact, and their level is constantly rising (Antoniadis and McKinley 2003, Leyval *et al*. 2006). Heavy metals present in soil are often subject to accumulation in the soil profile and under favourable conditions can be liberated in amounts that cannot be absorbed by the soil environment without side effects. In the literature that phenomenon is referred to as the Chemical Time Bomb (Czarnowska and Bednarz 2000).

Since the availability of metals in soil is closely related with the pH of the environment, the buffer capacity of soil is a highly important value characterising the soil. Understanding of the effect of the presence of construction materials in an urban soil on the buffer capacity of the soil will permit preparation of suitable reclamation and remediation operations. Proper course of action will be conducive to the assimilation of building materials in the soil environment. Also, such a course of action will not change the buffer capacity of the soil significantly, and thus will have no major effect on the cycle of heavy metals, or it will even have an inhibiting effect on the proliferation of those ions in the soil environment.

Thanks to its ability of buffering the environment, soil can – within certain limits – counteract the acidification of the environment, prevent latent salinity and alkalisation of the environment (Weaver *et al*. 2004).

The objective of the study was to demonstrate the effect of building materials present in soil on its buffer capacity.

MATERIAL AND METHOD

The loess soil used in the study (Typic Entrochrept acc. to FAO) was taken from a trial pit in Elizówka n/Lublin. The tests and examinations were performed for the surface horizon of the soil profile (0-15 cm).

The soil material was mixed with concrete, brick, foam concrete and mortar. Prior to the mixing, all of the building materials were ground and screened through a sieve with 1 mm mesh size. The mixtures of soil and fragmented building materials were prepared at weight ratio of 1:1. Model urbisols obtained through that procedure were stored at room temperature.

A parallel series of model urbisols was prepared with an addition of peat (Eutric Histosol), frequently applied as a "remediation" material after the completion of construction works. The peat was ground and screened through a sieve with 1 mm mesh size. Its content was constant in each mixture and amounted to 6% by weight.

For preliminary standardisation of the samples, the mixtures under study were moistened with distilled water in an amount of ca. 25% by weight, which falls within the moisture range between field water capacity and the wilting point for the loess soil, and then they were subjected to several drying-wetting cycles.

The samples were then subjected to thermal stress. In three cycles of six weeks each. In each cycle, the samples were stored – for the change – over one week at – 20^{o}C. and one week at 30^{o}C. All the time was kept steady humidity (25%).

The samples prepared as above were subjected to the basic physicochemical analyses. The assays comprised the particle size distribution/granulometric composition (with the method of Bouyoucose as modified by Cassagrande and Pruszyński), reaction (assayed in suspensions in distilled water and in 1 mol dm^{-3} solution of KCl at solid-liquid phase ratio of 1:2.5), organic carbon content (Analytik Jena TOC MULTI N/C 2000, HT 1300 carbon and nitrogen analyser).

The buffer capacity of soil is defined as the amount of acid or base which changes the pH of the solution by one unit. In the study, the measurement of the buffer capacity of the model mixtures of soil with building materials was conducted through measurement of changes in pH after adding hydrochloric acid or sodium hydroxide solutions to the model mixtures. From each mixture a series of twelve weighed portions were made, each of 5 g. The particular weighed portions were flooded with solutions of hydrochloric acid or sodium hydroxide, with concentrations of 0.1, 0.2, 0.4, 0.6, 0.8, 1.0 (mol l^{-1}), at the soil-solution ratio, by weight, of 1:2.5. In addition, suspensions of the soil and its model mixture in distilled water were prepared. After a period of 48 h, measurement of pH was made in each of the suspensions prepared as above.

RESULTS AND DISCUSSION

Table 1 presents the basic physicochemical characteristics of the material tested. As can be seen from Table 1, dominant in the soil were the fractions of silt (59%) and clay (36%), the content of organic carbon was at the level of 1.3%, and pH was slightly alkaline.

The fragmented building material was characterised by a particle size distribution with similar percentage shares of the particular fractions, the dominant fraction being the silt fraction.

The pH (measured in water) of the building materials used was alkaline and varied from 8.18 in the case of mortar to 12.26 in the case of concrete.

The peat used in the experiment was characterised by organic carbon content at the level of 33%, while its pH measured in water was at the level of 5.4.

Table 1. Physiochemical characteristics of the tested soil material

Sample	Granulometric composition*			C_{org} (%)	pH	
	sand	silt	clay		H_2O	KCl
Starting material						
Soil – (S)	5	59	36	1.30	7.93	7.64
Brick – (B)	17	51	32	n.o.	8.75	8.49
Concrete – (C)	23	49	28	n.o.	12.26	11.58
Foam concrete – (Fc)	36	37	27	n.o.	9.55	9.39
Mortar – (M)	30	44	26	n.o.	8.18	7.87
Peat (P)	n.o.	n.o.	n.o.	33. 20	5.40	5.10
Mixtures without peat						
S + B	27	40	33	1.41	8.22	7.64
S + C	45	34	21	1.34	11.58	11.04
S + Fc	42	40	18	1.55	8.09	7.81
S + M	43	37	20	1.30	9.03	8.78
Mixtures with peat						
S + P	39	43	18	4.40	6.27	5.78
S + B+ P	29	41	30	4.10	6.18	6.06
S + C + P	41	34	25	3.60	9.76	9.48
S + Fc + P	40	38	22	4.50	7.52	7.41
S + M + P	47	31	22	3.95	7.10	7.14

*– sand (1-01 mm), silt (0.1-0.02 mm), clay (> 0.02 mm), n.o. – not determined.

The particle size distribution of the model mixtures of the soil with the building materials is characterised by an increased content of the sand fraction. That fraction, except for the mixture with brick, is dominant for the mixtures tested. The addition of peat to the mixtures did not alter that tendency. The content of organic carbon in the model mixtures of the soil and building materials increased slightly compared to the natural soil. Whereas, as expected, in the mixtures with peat "remediation" the content of organic carbon increased, on average, three-fold compared to the initial material.

Table 2 presents the values of pH of the particular components of the model mixtures after the addition of solutions of HCl or NaOH with concentration of 1 mol dm^{-3}.

Table 2. The pH level of soil and building materials in different environments

Materials	HCl (1 mol L^{-1})	Water	NaOH (1 mol L^{-1})
Soil	1.8	8.2	11.4
Brick	1.4	8.7	12.2
Concrete	3.8	12.3	12.6
Foam concrete	3.6	9.5	12.3
Mortar	2.1	8.2	12.3
Peat	3.7	5.4	9.0

The soil, brick and mortar display in water nearly identical values of pH (slightly alkaline), while concrete and foam concrete have pH values exceeding 9. Peat has a weakly acid reaction. After the addition of 1M sodium hydroxide, the components of the model mixtures have similar high values of pH, which indicates their low buffer capacity with relation to substances of alkaline character (BNC – base neutralisation capacity). Only peat is characterised by a lower value of pH. After the addition of 1 M hydrochloric acid, only foam concrete has reaction value above 6, while the remaining components of the mixtures are characterised by a relatively strongly acid reaction. This is most probably related with low buffer capacity of those components with relation to substances with acid character (ANC – acid neutralisation capacity), e.g. atmospheric precipitations that may have relatively low pH.

Changes of pH values that were caused by the thermal cycles are presented in the graphs in Figures 1-3. At the same time, the graphs presented in the Figures illustrate the tendencies in the changing level of buffer capacity of the samples under analysis. All changes in pH values, for all variants of the experiment, were referenced to the natural soil. As can be see from Figures 1-3, the changes in pH and in buffer capacity can be positive (increase of pH) or negative (decrease of pH). Positive changes occurred only in the case of samples without peat, in the systems of sample-H_2O and sample-HCl. In the remaining cases the variation in the behaviour of the samples under study was more complex (Figs. 1-3).

Figure 1 presents the values of pH in H_2O for the soil and its mixtures. After the addition of peat the pH of the soil decreased significantly, which indicates a lower buffer capacity with relation to substances with acid character. The addition of brick (with the lowest ANC value) causes a reduction of the ANC of the soil (dilution), and therefore the greatest drop in pH value after the addition of the acid peat. The addition of alkaline concrete causes an increase of pH of the soil, as the concrete also has a higher buffer capacity with relation to alkaline substances. The effect of the remaining components of the mixtures under study on changes in pH is much less pronounced.

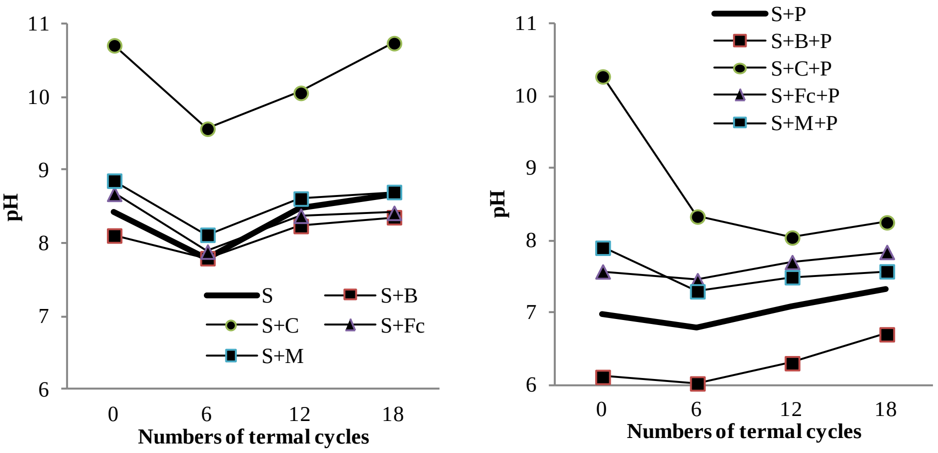

Fig. 1. Changes in the buffer capacity of model mixtures in water depending on the duration of the temperature cycles. (S) corresponds to the natural soil; (B) – brick; (C) – concrete; (Fc) – foam concrete; (M) – mortar; (P) – peat

The effect of the temperature cycles is the most observable in the soil mixtures with concrete and peat. In the mixture of the soil with concrete alone, the pH increases strongly, then decreases and undergoes further growth as the temperature cycles continue. Such a run of the pH change-number of cycles relation is the result of kinetic effects. Initially, easily soluble components of concrete, that did not have time to react with soil components, are present in notable amounts in the soil solution, which causes an increase of its pH. Those components get neutralised quickly in the soil and the pH decreases. Further neutralisation of less easily soluble components of concrete causes a slow increase of pH with the passage of time of the experiment. Similar effects are observed in the mixture of the soil with concrete and peat, but in this case, due to the acid character of peat, the pH values measured are lower. Effects of slow stabilisation of equilibrium of the reaction of the soil with organic substance added are also observable in mixtures of the soil with peat, soil with peat and brick, and soil with peat and mortar, where a slow increase of pH values takes place, whereas in the remaining mixtures the level of pH initially decreases, and then there is an increase of pH values.

Figure 2 presents the values of pH of the model mixtures after the addition of hydrochloric acid, characterising the changes of ANC buffer capacity.

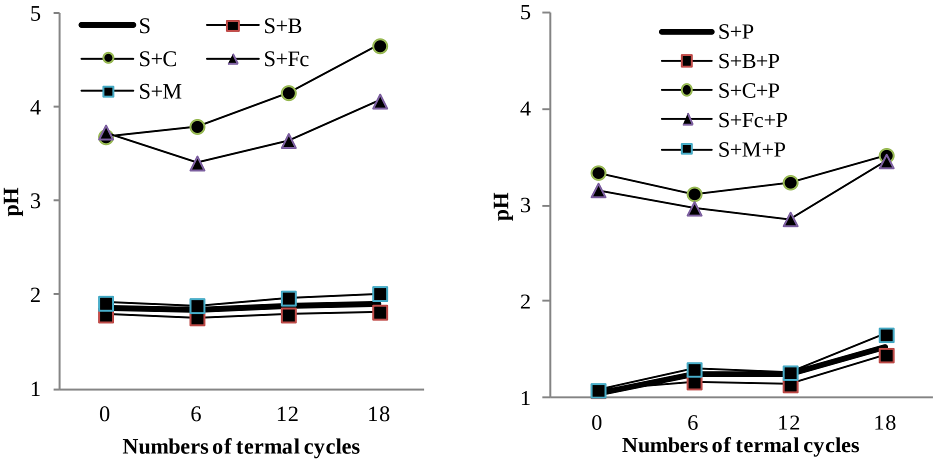

Fig. 2. Changes in pH of model mixtures after the addition of hydrochloric acid, depending on the duration of the temperature cycles. Symbols used as in Figure 1.

Values of pH in 1M HCl are a measure of the buffer capacity of the mixtures with relation to substances of acid character. The higher the value of pH after the addition of HCl solution to a mixture, the higher the ANC value of the mixture. In spite of the relatively low value of pH(H_2O) of the foam concrete, its ANC, like that of concrete, is relatively high. Hence the pH value of mixtures with concrete, after the addition of the acid, decreases the least, which is also observable for the soil with an addition of the concretes and peat. The addition of peat alone, due to its acid character, reduces the ANC value of the soil.

The effect of the time of stabilisation (temperature cycles) on the value of ANC of the mixtures is relatively small. It is the most pronounced in the mixtures of the soil with concretes, which is related with the slow kinetics of releasing substances with alkaline character from the materials added, described above, causing an increase in ANC with the passage of time of the experiment.

Figure 3 presents changes in the buffer capacity of the model mixtures in an alkaline environment.

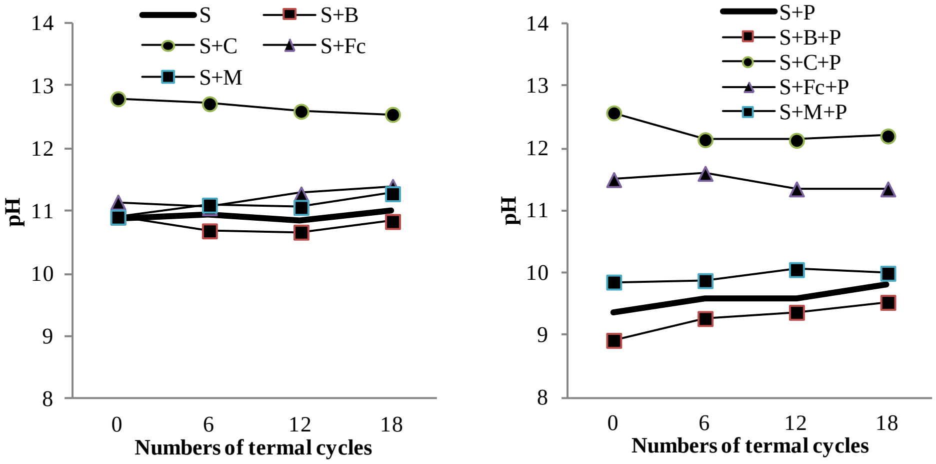

Fig. 3. Changes in pH of model mixtures after the addition of sodium hydroxide, depending on the duration of the temperature cycles. Symbols used as in Fig. 1.

The value of pH in 1M NaOH is a measure of the buffer capacity of the mixtures with relation to substances with alkaline character (BNC). The higher the value of pH after the addition of NaOH solution to a mixture, the lower the BNC value of the mixture. The value of BNC for mixtures of the soil with concrete and foam concrete is the lowest, as the buffer capacity for concrete and foam concrete determined in the sodium hydroxide solution was the lowest. And vice versa, mixtures containing acid peat display the highest values of BNC.

The value of BNC of the mixtures under study, as in the case of ANC, changes only slightly during the temperature cycles. Both of the values increase during the experiment in the case of mixtures containing the concretes. In the mixtures containing peat, the value of BNC undergoes a slight decrease in the course of the temperature cycles, which is caused by reactions of organic matter with the components of the soil, leading to neutralisation of acidity of peat.

CONCLUSIONS

The following conclusions were formulated on the basis of the measurements performed:

1. The buffer capacity of the soil undergoes notable changes after the addition of building materials and “remediation” of the mixtures with peat. The building materials increase the buffer capacity of the soil with relation to substances of acid character, while the addition of peat increases the buffer capacity of the soil and its mixtures with relation to substances of alkaline character.
2. During the cyclic changes of temperature a decrease of differences was observed in the buffer capacity among the particular mixtures and between the mixtures and the soil.
3. The changes in the buffer capacity of the soil are significant enough to be used in the future for counteracting environmental pollution both with heavy metals and with other substances whose mobility in the soil environment is closely related with the reaction of the environment.

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WPŁYW OBECNOŚCI MATERIAŁÓW BUDOWLANYCH NA ZDOLNOŚCI BUFOROWE GLEBY LESSOWEJ

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Streszczenie. Zbadano wpływ obecności gruzu materiałów budowanych na zdolności buforowe gleby lessowej (Typic Entrochrept wg FAO). Dołożono do niej zmielone materiały budowlane: cegłę, beton, beton komórkowy i zaprawę. Dodatkowo przygotowano takie same mieszaniny, do których dodano 6% torfu jako materiału rekultywującego modelowe mieszaniny. Następnie poddano je stresowi termicznemu i zamrażano do temperatury –20°C, później próbki przenoszono do temperatury 30°C, utrzymując cały czas stałą wilgotność na poziomie 25% wagowych, co zawiera się w przedziale wilgotności pomiędzy polową pojemnością wodną a punktem więdnięcia dla gleby lessowej. W toku prowadzonych prac stwierdzono istotny wpływ materiałów budowlanych na zdolności buforowe gleby lessowej. Zmieniały się one w zależności od rodzaju dodanego materiału budowlanego, czasu prowadzenia stresu termicznego, jak i dodatkowej obecności torfu. Stwierdzono, że obecność materiałów budowlanych zwiększyła pojemność buforową gleby w stosunku do substancji o charakterze kwaśnym. Obecność torfu przyczyniała się do odwrócenia tego procesu. Zdolność torfu do rekultywacji gleby zdegradowanej materiałami budowlanymi była dodatkowo potwierdzona w wynikach badań wpływu stresu termicznego na zdolności buforowe gleby i jej mieszanin. Wraz z wydłużaniem się czasu prowadzenia stresu termicznego zmniejszały się różnice w pojemności buforowej między poszczególnymi mieszaniami i glebą.

Słowa kluczowe: pojemność buforowa, materiały budowlane, gleba lessowa