

Soil Buffering Capacity - A Measure of Soil Resilience

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Introduction

Buffering is the ability of the soil to resist a change in the ion concentration of its solution following the addition or removal of the ion (FROSSARD et al., 1992; HOLFORD, 1988).

Ions entering the soil are distributed between the solution and the solid phase, depending on the physical and chemical characteristics of the soil. Sorption onto the solid phase would appear to involve at least two processes, differing in their energy contents. These two processes can be described by a two-term Langmuir equation. The less stable form of sorption is physical adsorption, while the energetically more stable bond may differ in nature depending on the properties of the sorbed material, e.g. chemisorption, precipitation, formation of chemical compounds, fixation.

The soil buffering capacity (BC) can be calculated from the Langmuir equation:

$$BC = \frac{dQ}{dc}$$

or from the linear relationship Q/I (EVANGEIOU & KARANTHANASIS, 1986).

Each soil has various buffering capacity parameters for any given ion, e.g. maximum buffering capacity, equilibrium buffering capacity and actual buffering capacity. This latter is of great importance for the chemical impact of the soil. It shows the buffering ability of a soil already loaded with chemicals. The actual buffering capacity is always much lower than the maximum buffering capacity, calculated by extrapolation from the unloaded state (FÜLEKY & VÉGH, 1984).

When considering the chemical impact of the soil it is important to know which phase the chemicals are sorbed in. From the point of view of the environment, stable bonds are more favourable, while physical adsorption is more satisfactory for plant nutrition.

After the soil is exposed to one extremely high dose of chemicals or to several smaller doses, the soil is unable to buffer the effects of a further dose. In this case, most of the chemicals would remain in the soil solution, possibly migrating down in the soil and later reaching the groundwater.

In the present paper the dependence of buffering capacity on chemical loading was studied in the case of phosphorus and potassium.

Material and Methods

The experiments were carried out on four Hungarian soils. Some main properties of these soils are presented in Table 1, together with their clay mineral

Table 1
Some characteristics of the soils examined

No. of soil	pH (KCl)	Clay %	Clay mineral content of the clay fraction, %							
			Ill.	Ka.	Chl.	Sm.	Ve.	Ill.- Sm.	Ill.- Chl.	Ill.- Ve.
8.	7.1	27.6	43.0	-	19.0	10.0	6.0	18.0	3	1.0
19.	5.7	36.3	29.0	-	7.0	47.0	8.0	5.0	3	3.0
24.	3.3	31.8	51.3	23.8	-	8.9	3.7	8.7	-	3.6
34.	7.4	5.4	50.4	-	22.5	13.6	-	13.5	-	-

composition. The soils were incubated with simultaneously increasing quantities of phosphorus and potassium for six months at constant room temperature and at a moisture content equivalent to their field water capacity. The P and K quantities, applied in the form of KH_2PO_4 , were: 0; 20; 40; 80; 160; 320; 640 and 1000 mg P kg^{-1} and 0; 12.5; 25; 50; 100; 125; 200; 400; 800 and 1250 mg K kg^{-1} .

After six months' incubation, soils with the above P and K rates were shaken in a circular shaker for 24 hours at a soil-water ratio of 1:10. The phosphorus and potassium contents of the centrifuged solution were determined, after which the bound P and K quantities were calculated. These quantities were illustrated as the function of equilibrium concentration, and the PBC and KBC values were calculated for given concentrations.

A two-term Langmuir function was used to describe the potassium and phosphorus adsorption:

$$y = \frac{A_1 \cdot K_1 \cdot c}{(1 + K_1 \cdot c)} + \frac{A_2 \cdot K_2 \cdot c}{(1 + K_2 \cdot c)}$$

where Q was the quantity of potassium or phosphorus originally present in the soil or adsorbed after preliminary fertilization and incubation.

Results and Discussion

The buffering capacity values were determined at equilibrium concentrations of 0, 0.2; 10; 20 and 40 mg P and K l⁻¹ after computer curve fitting by differentiating the function at the above points. Table 2 contains a number of values calculated for buffering capacity.

Table 2
K buffering capacity (l kg⁻¹) of some selected treatments

No. of soil incubation K, mg kg ⁻¹	Equilibrium concentration, mg l ⁻¹				
	0	0.2	10	20	40
19-0	131.29	125.06	36.65	23.46	15.34
19-125	96.01	94.22	44.24	25.34	16.47
19-400	45.21	44.91	33.41	25.86	17.06
24-0	91.92	87.86	28.96	20.51	15.96
8-0	36.81	36.37	22.28	15.66	9.82
34-0	5.83	5.83	5.82	5.81	5.79

The K adsorption isotherms of soil No. 19/0 can be seen in Fig. 1. In soil which received no potassium fertilizer, two bonds with different energies can be distinguished. The stronger bond, with greater energy (Process 1), can be observed at lower equilibrium concentrations. It can be seen, however, that even at the lowest concentrations, bonds are formed at the lower energy sites too (Process 2). If the soil was preliminarily incubated with a medium rate of K (125 mg K kg⁻¹), the higher energy sites were already occupied and Process 1 practically disappeared. After incubation with higher K rates (400 mg K kg⁻¹), the curved function straightened out and shifted towards higher equilibrium concentrations, showing a shape similar to that of sandy soil No. 34/0 (Fig. 2).

Soil No. 19 has a considerable smectite content, giving it the highest K-binding capacity of the four soils studied. The K-binding ability of the soils provides reliable information on the K buffering capacity values (Table 2). In the case of soil No. 19, as the previous K-load increased, there was a gradual reduction in the K buffering capacity of the soil at low equilibrium concentrations (0; 0.2). By contrast, at higher equilibrium concentrations (10; 20; 40) the

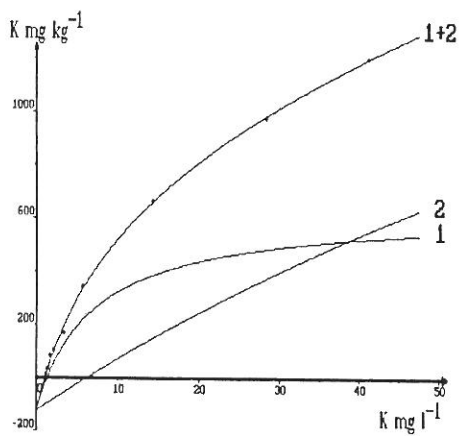


Fig. 1

K adsorption isotherms of soil No. 19/0

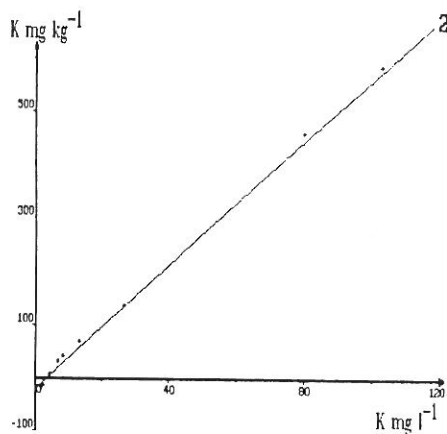


Fig. 2

K adsorption isotherm of soil No. 34/0.

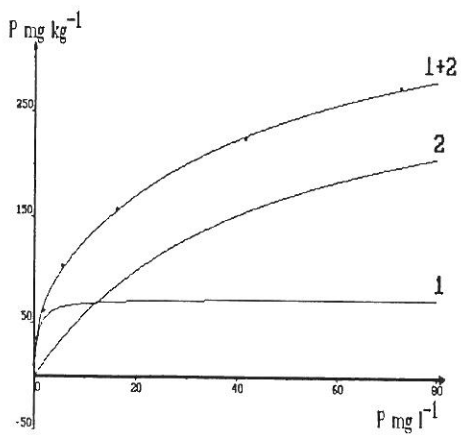


Fig. 3

P adsorption isotherms of soil No. 19/0.

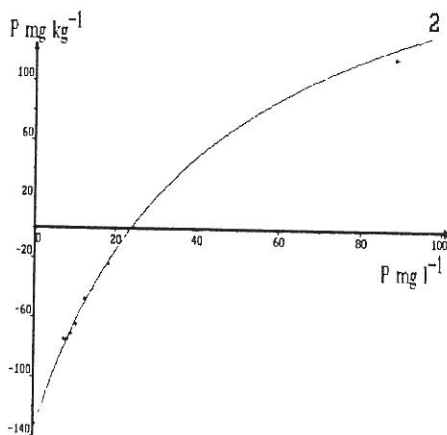


Fig. 4

P adsorption isotherms of soil No. 19/320.

buffering capacity values were almost identical. This would appear to indicate that, irrespective of the previous K loads, at above values of 160 mg kg⁻¹ the soil is unable to compensate for further K loads, i.e. above this K fertilizer rate the soil exhibits a lower, but constant buffering capacity. Much the same can be said of soils Nos. 8 and 24, though due to their illite-kaolinite-chlorite clay mineral composition, these automatically have a lower buffering capacity. Naturally, the buffering capacity of the sandy soil No. 34 is substantially lower. For this soil, at equilibrium concentrations of 0 - 100 mg K l⁻¹, the buffering capacity (5.8 l kg⁻¹) is identical over the whole measurement range, irrespective of the preliminary K load of the soil (Fig. 2). At high previous K loads (400 K kg⁻¹), sandy soil No. 34 practically loses its K-buffering ability and the isotherm becomes a straight line parallel to the x-axis. At this point the soil is quite incapable of buffering the environment from any further K stress.

Table 3
P buffering capacity (l kg⁻¹) of some selected treatments

No. of soil incubation P, mg kg ⁻¹	Equilibrium concentration, mg l ⁻¹				
	0	0.2	10	20	40
24-0	211.12	271.67	14.75	10.4	6.01
8-0	233.98	88.91	8.50	5.10	2.44
34-0	81.93	56.50	3.71	3.28	3.15
19-0	111.94	70.53	5.26	3.56	2.03
19-80	15.34	15.02	6.49	3.56	1.55
19-320	8.79	8.71	5.84	4.17	2.42

The phosphorus buffering capacities of some of the soils and treatments examined are presented in Table 3. As can be seen, the maximum buffering capacity of the acidic soil No. 24 has a very high value, and at any equilibrium concentration the phosphorus buffering capacity of this soil is greater than that of the other soils tested. For all soils and treatments the phosphorus buffering capacity gradually decreased as the equilibrium concentration rose. For the soil samples in treatments 8/0, 34/0, 19/0, 19/80 and 19/320, almost identical phosphorus buffering capacity values were obtained at equilibrium concentrations of 10 mg l⁻¹ or more.

As can be seen for soils Nos. 19/0 and 19/320 (Figs. 3 and 4), in soil not previously fertilized with phosphorus the stronger and weaker bonding processes can both be distinguished, while for soils previously incubated with a substantial quantity of phosphorus, the stronger binding process can no longer be observed. By contrast, although sandy soil No. 34/0 was not subjected to

phosphorus treatment, phosphorus was only bound from the soil solution by a single process. This was obviously due to the high sand, the low clay and the consequent low colloid content. As the previous load increases, the adsorption isotherm gradually shifts towards the higher equilibrium concentrations and the initial section becomes less steep, while the steepness of the saturation phase is the same for soils with and without previous loads.

In summary it can be said that the buffering capacity of the soils depends to a great extent both on previous chemical stress and on the present load. In the case of small loads, the soil is able to compensate for the effect of external stress with the aid of the strong binding process, thus exhibiting great buffering capacity. In the case of large loads, the role of the strong binding process is reduced and the weaker binding process becomes dominant over a wide concentration range.

Soils containing the clay mineral smectite and high clay content, are better able to buffer K stress than those containing illite-chlorite-kaolinite as clay minerals.

Soils not previously treated with phosphorus are able to buffer phosphorus stress over a wide concentration range, especially if they have a very acidic pH and an adequate clay content.

Summary

The effect of previous chemical stress followed by current stress was studied on the buffering capacity of four Hungarian soils. Both the preliminary and the later stress took place over a wide range of phosphorus and potassium concentrations (0-1000 mg kg⁻¹). As the preliminary stress increased, both the phosphorus and the potassium buffering capacity decreased at low equilibrium concentrations, i.e. in the case of low actual stress. At high actual stress, the buffering capacity of soils with a satisfactory colloid content became constant at an extremely low value. In sandy soils the soil may completely lose its buffering capacity, particularly in the case of potassium stress.

The high buffering capacity of the soils can be attributed to the presence of a strong, high-energy binding process. The reduction in the buffering capacity, on the other hand, can be explained by the saturation of high-energy sites and the cessation of this process.

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