Int. Agrophysics, 2001, 15, 51-54

INTERNATIONAL
Agrophysics
www.ipan.lublin.pl/int-agrophysics

Physicochemical reclamation of saline soils using coal powder

T. Raychev[1], S. Popandova[1], G. Józefaciuk[2], M. Hajnos[2], and Z. Sokołowska[2]*

[1]Institute of Soil Science and Agroecology "Poushkarov", Shosse Bankya 5, 1005 Sofia, Bulgaria
[2]Institute of Agrophysics, Polish Academy of Sciences, Doświadczalna 4, P.O. Box 201, 20-290 Lublin 27, Poland

Received March 27, 2000; accepted April 19, 2000

A b s t r a c t. A new method of saline soils reclamation using coal powder was proposed and tested in practice in pot experiments on Halaquept soil with alfalfa as a testing plant. The experiment showed the possible applicability of the method in practice.

K e y w o r d s: reclamation, saline soils

INTRODUCTION

Saline soils reclamation is one of the main problems in the future for humans [13]. Reclamation of saline soils uses many different methods as physical amelioration (deep ploughing, subsoiling, sanding, profile inversion), chemical amelioration (amending of soil with various reagents: gypsum, calcium chloride, limestone, sulphuric acid, sulphur, iron sulphate), electro-reclamation (treatment with electric current). The most effective, hydrotechnical amelioration methods, are based on the removal of exchange and soluble sodium and changing the ionic composition of soils by added chemicals with parallel leaching of sodium salts out of the soil profile [2]. The result of such procedures is the decrease of pH and osmotic pressure of soil solution thus promoting good conditions for the decrease of the dispersion of soil colloidal fraction. The main disadvantage of the above methods [14] is the necessity of using hydromelioration equipment and huge amounts of water. Leaching of sodium salts can pollute ground water and neighbouring water courses. The loss of natural soil organic matter to a great extent can also occur. The biological amelioration methods using living or dead organic matter (crops, stems, straw, green manure, barnyard manure, compost, sewage sludge) [7,17] have two principal beneficial effects on reclamation of saline and alkaline soils: improvement of soil structure and permeability thus enhancing salt leaching, reducing surface evaporation and inhibition of salt accumulation in surface soils, and release of carbon dioxide during respiration and decomposition. In the latter methods large amounts of organic matter should be applied in a long term treatment.

It seems that by amending a saline soil with a chemically stable organic material, being a permanent source of the organic matter of a high humification degree the positive amelioration effects mentioned above can be reached in a single reclamation step. Such material of high CEC can adsorb a part of soluble salts, decrease the pH and promote aggregation. The drop of pH below 8 can cause positive edge charging of clay minerals and the electrostatic adsorption of the organic compounds. The physical adsorption and polyvalent cations bridging of high molecular weight compounds on inorganic surfaces can additionally stabilise the newly formed aggregates. The selection of reclamation agents should take into account not only their influence on the soil itself, but also their price and environmental hazard. It seems that black or brown coal powders can be satisfactory agents.

The synergic reclamation effect can possibly be reached by combining the coal with $FeSO_4$ additions.

The purpose of the present work was to test the possibility of coal powder application in saline soils reclamation.

MATERIALS AND METHODS

The investigations were carried out on the A-horizon samples of Halaquept soil (Belozem, Plovdiv district Bulgaria). The exchange capacity of this soil was estimated as the difference between the extracted and soluble salts with the Bower [1] method. The amount of soluble sodium and

*Corresponding author e-mail: jozefaci@demeter.ipan.lublin.pl

the electric conductivity was determined in soil : water = 1:5 extracts and recalculated for the saturated soil paste solution. The characteristic of the soil is presented in Table 1 and the composition of the soil solution in Table 2. The anthracite coal powder used as a soil conditioner contained 44% of carbon and 15% of ashes. Selected data on the coal water extract are included in Table 2.

T a b l e 1. Physicochemical characteristics of the soil used

Parameters	Soil
pH (H_2O)	8.0
Electric conductivity of saturated paste κ, dS m^{-1}	4.97
CEC at pH 8.2, cmol kg^{-1}	20.0
Clay %	21.4
Na soluble, cmol kg^{-1}	10.2
Na exchangeable, cmol kg^{-1}	5.0

The soil was equilibrated with the respective amendments at 50% soil water capacity and the soils from variants 2 and 4 were subsequently washed with distilled water of the amount calculated basing on the electric conductivity of the soil solution according to the formula of Volobuyev [16]. After the moisture of the washed soils decreased to 50% of soil water capacity (10 days), 50 alfalfa plants per pot were seeded. At the 3rd leaf stage, some of the plants were repelled and 10 plants were cultivated further. During plant growth the soil moisture was kept roughly constant at 60% soil water capacity. The experiments were performed in four replicates.

The leachates from the pots and the 1:5 soil : water extracts were analysed for sodium (flame photometry), iron (AAS), pH and electric conductivity. Exchange sodium with the Bower method [1] and exchangeable iron from the difference between mobile and soluble iron forms were estimated in soils.

T a b l e 2. Soluble salt composition of the soil and the coal material used

Material	pH H_2O	κ (dS m^{-1})	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	K^+	Na^+
			(cmol kg^{-1})							
Soil	8.0	4.97	0.0	0.469	0.141	12.47	2.47	1.71	0.038	10.22
Coal	4.6	3.24	0.0	0.095	0.000	6.75	2.10	0.99	0.066	1.91

The pot experiments with alfalfa as a testing plant on the original and on coal powder and Fe II sulphate amended soil were performed. The pots containing 0.5 kg of soil with different combinations of the amendments were prepared according to the following scheme:

0. original soil (control),
1. original soil + NPK,
2. original soil + NPK + $FeSO_4$, washing with water,
3. original soil + NPK + $FeSO_4$,
4. original soil + NPK + $FeSO_4$, washing with water + coal powder,
5. original soil + NPK + $FeSO_4$ + coal powder,
6. original soil + NPK + coal powder.

The amount of NPK was 100 mg N, 100 mg P and 125 mg K per pot. The dose of $FeSO_4$ was 3 g $FeSO_4$*7 H_2O per pot, added as a water solution. Since no literature information is currently available on coal powder dosages, we calculated this from the data on the amount of humic acids (HA) necessary to coagulate the sodium montmorillonite suspension which, according to Tarchitzky *et al.* [15], is in the range 37-150 g of HA per 1 kg of clay at pH 8.0. Taking into account the granulometric composition of the soil used and the composition of coal, the required amount of coal powder should be 0.9-3.5 g per 100 g soil. An average dose of the air dry coal powder equal to 1.75 g per 100 g of soil was then applied in the present experiment.

In dry plant material, nitrogen (Kjeldahl method), phosphorus (ammonium molybdate), sodium and potassium (flame photometry), calcium, magnesium and some microelements (AAS) were determined. In fresh plants the divalent iron was determined additionally with o-phenantroline.

RESULTS AND DISCUSSION

The physicochemical characteristic of the soils after 6 months of plants growing as well as the yield of the plants are shown in Table 3. The second crop yield was presented because the differences in biomass were not statistically significant at the first stages of plant growth. This could be caused either by too short time of soil equilibration before plant seeding or by the salt uptake by the first crop (decrease of the salt barrier) as well as by time progress of the physicochemical reaction of the soil with the amendments.

After 6 months the pH of every variant did not significantly change but the solution electric conductivity decreased markedly. In both variants with washing, the amount of soluble sodium decreased sharply. The highest amount of soluble iron forms was noted in the variant 2, which is a reclamation standard. Additional amendment of this variant with coal powder (variant 4) gave no significant change of soluble and exchangeable sodium. However, in this variant a significant decrease of soluble iron occurred, which was

Table 3. Soil chemical data and plant yield after 6 months of the vegetation experiment

Variant	pH H_2O	κ (dS^{-1} m^{-1})	Na, soln. (cmol kg^{-1})	Na, exch. (cmol kg^{-1})	Fe, soln. (cg kg^{-1})	Biomass (g pot^{-1})
Original soil (S)	8.0	4.97	10.22	5.00	0.00	0.0
1. S+NPK (FS)	8.0	2.78	5.30	1.60	2.00	2.5
2. (FS)+$FeSO_4$, W	8.0	1.26	2.39	1.11	1.96	21.3
3. (FS)+$FeSO_4$	7.9	2.53	5.10	0.24	0.10	19.3
4. (FS)+$FeSO_4$, W, C	7.7	1.36	2.07	1.11	0.42	20.3
5. (FS)+$FeSO_4$, C	7.7	2.12	4.20	0.80	0.30	28.2
6. (FS), C	8.0	2.46	4.90	1.94	0.20	25.0

Abbreviations: W - leaching with water, C - coal addition.

probably caused by iron bonding with the coal material. The plant yield was close to the previous variant.

The most effective was reclamation variant 5, in which both coal powder and iron sulphate were added to the soil without washing with water. The yield of biomass was more then 30% higher than in the standard one. The next effective was variant 6 with only coal powder addition, where the biomass yield was 17% higher than in the standard reclamation procedure. In comparison to the standard variant, the total amount of soluble iron was here very low, however, this was two times higher than in the control pots.

The content of macroelements in the plants was similar for different reclamation variants and the microelements content was in the range of 20-50 mg kg^{-1} for Zn, 100-150 mg kg^{-1} for Mn and 100-200 mg kg^{-1} Fe. The differences in total uptake of the elements from the soil can then be attributed to the total plant yield.

As mentioned previously, soil structure stabilisation by addition of organic compounds is time dependent and related to the amount added. To observe such effects, additional experiments were performed using the same soil and growing conditions but increasing doses of the coal powder and the duration of the soil pre-equilibration (to 30 days before the plants seeding). These experiments were prepared according to the scheme:

7. original soil,
8. original soil + NPK + $FeSO_4$, washing with water,
9. original soil + NPK + coal (20 t ha^{-1}),
10. original soil + NPK + coal (40 t ha^{-1}),
11. original soil + NPK + coal (60 t ha^{-1}).

Table 4 shows the yields of alfalfa taken from the above experimental variants at the fourth crop.

As with the previous variants, it can also be seen from the present ones that the best conditions for plant growth occurred when coal and iron together and/or only coal were applied. The increase of the duration of soil pre-equilibration markedly increased the effectiveness of the amendments activity.

Based on the results obtained, a new method for saline soils reclamation can possibly be outlined. The soil should be amended with black or brown coal powder, possibly as waste materials from coal mines. The powder can be applied in the air dry state or as water suspensions. Doses of about 20 t ha^{-1} or higher can be recommended, depending on soil properties. The presence of humus-like substances in coal materials enriches the soil in stable organic matter of high cation exchange capacity and aggregation properties. High stability of coals can enable the slow release of humus-like compounds to the soil. Thus the coal material may be regarded as a semi-permanent source of humus-like organic matter. The iron II sulphate can be applied simultaneously as water solution in doses equivalent to the dose of gypsum. Its hydrolysis and oxidation can lead to further reductions of soil pH and the production of amorphous iron hydroxides, which serve as cementing agents. Iron industrial wastes can also be applied. The added amendments should be mixed with the upper layer of the saline soil under reclamation. Further irrigation of the soil is not necessary. The interaction of the added materials with soil minerals and solutes should

Table 4. Yield of biomass for the subsequent crops of alfalfa seeded after 30 days of soil pre-equilibration with the amendments

Variant	Crop No. / biomass (g)				Sum
	I	II	III	IV	I-IV
7. soil (S; FS)		no germination			0.0
8. (FS) + $FeSO_4$, W	2.72	3.58	5.61	2.46	14.37
9. (FS) + C (20 t ha^{-1})	3.30	9.50	23.48	27.95	64.23
10. (FS) + C (40 t ha^{-1})	3.97	9.67	30.77	30.94	75.35
11. (FS) + C (60 t ha^{-1})	4.28	9.59	33.07	31.12	78.06

Abbreviations as in Table 3.

diminish toxic concentrations of salt and stabilise aggregation state of the soil.

The proposed method has the following advantages:

- decreasing the soluble salt level and its toxicity for plants,
- enriching of the soil with structure forming organic matter,
- minimizing the environmental pollution hazard,
- minimizing financial input (no hydro-technical amelioration),
- allowing the use of industrial wastes in an ecologically correct way.

CONCLUSION

A method of saline soil reclamation with coal powder was evaluated. Biological and soil chemical tests showed the possible applicability of this method in practice, however, field tests are necessary to draw final conclusions.

REFERENCES

1. **Bower C.A., 1996.** Fixation of ammonium in difficultly exchangeable form under moist conditions by soils of Semiarid Regions. Soil Sci., 70, 87-95.
2. **Chhabra R., 1994.** Soil salinity and water quality. Oxford and IBH Publ. Co. New Delhi.
3. **Ganev S., 1990.** Modern Soil Chemistry (in Bulgarian). Nauka i Isskustvo Sofia Ed.
4. **Kauritchev I.S. and Bazilinskaya M.B., 1965.** On the migration of organic matter and iron in salt affected soils of West Siberia (in Russian). Izw. T. SCH. A. 1, 17-27.
5. **Kauritchev I.S., Kulakov E.W., and Nozdrunova E.N., 1958.** Problems of forming and migration of iron-organic compounds in soils (in Russian). Pochvovedenie, 12, 36-41.
6. **Kiriushin W.I. and Lebedeva I.N., 1975.** The influence of salt level on humus composition and some properties of humic acids (in Russian). Pochvovedenie, 4, 67-74.
7. **Matsumoto S., Zhao Q., Yang J., Zhu S., and Li L., 1994.** Salinisation and its environmental hazard on sustainable agriculture in East Asia and its neighbouring regions. Trans. 15th Congress Soil Sci., Mexico, 3a, 236-255.
8. **Nikolov N. and Zolotareva E., 1990.** Method of extraction of mobile phosphates, Ca, Mg, K, nitrates, Fe, Mn, Cu and Zn from soils (in Bulgarian). Bulg. Patent Nr 50363/17.04. INRA, Sofia.
9. **Pak K.P., 1975.** Solonetz Soils of the Soviet Union and Ways of Increasing their Fertility. Kolos Moscow Ed. (in Russian).
10. **Panov N.P. and Kokurina E.I., 1967.** Organic matter of chernozem solonetz soils of Irtish river basin (in Russian). Izw. T. SCH. A., 1, 119-133.
11. **Penkov M., Dzhuninski B., and Kavardzhiev Ya., 1985.** Reclamation of defected soils (in Bulgarian). Zemleizdat Sofia Ed.
12. **Raychev T., Popandova S., Józefaciuk G., and Hajnos M., 1990.** Effect of humic substances on the rate of exchangeable Ca and K ions desorption from montmorillonite. Zesz. Probl. Post. Nauk Roln., 338, 279-292.
13. **Szabolcs I., 1994.** Prospects of soil salinity for the 21st century. Trans. 15th Congress Soil Sci., Mexico, 1, 123-142.
14. **Tanji K.N., 1995.** Agricultural salinity assessment and management. Scientific Publishers Jodphur (India).
15. **Tarchitzky G.A., Chen Y., and Banin A., 1993.** Humic substances and pH effects on sodium and calcium montmorillonite flocculation and dispersion. Soil Sci. Soc. Am. J., 57, 367-371.
16. **Volobuyev W.R., 1975.** Calculation of Irrigation of Saline Soils (in Russian). Kolos Moscow Ed.
17. **Wang Z.Q. and Li L.Q., 1990.** Salinization in China and its prevention, studies on the prevention of land degradation in China. Chinese Sci. Technol. Press, Bejing.