# Migration and Accumulation of Easily Soluble Salts in the Romanian Plain

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The Romanian Plain, and especially its north-eastern part, represents the unit with the largest areas of halomorphic soils (over 100 000 ha). It is here that soils with the highest degree of salt accumulation, groundwaters with the highest degree of mineralization, as well as lakes with the highest salt content occur in Rumania. Mainly chlorides and sulphates constitute the accumulated salts.

The principal sources of all these salts are the numerous salt cores — some of which are outcropped — or the saliniferous rocks occurring in the hilly region close to the Subcarpathian Bend [4, 5, 6, 9, 12]. A part of the salts originating from these rocks is carried to the plain by surface waters or even groundwaters, and may accumulate in some areas under specific local conditions. The great extent of halomorphic soils in the north-eastern part of the Romanian Plain is due to the existence of some large areas which cumulate a variety of local conditions (in a relatively arid climate) promoting salt accumulation in soils and groundwaters. The climatic conditions of the Romanian Plain do not represent by themselves a factor of salt accumulation in the soil. However, the relatively high mean annual temperatures (9 – 11 °C) and especially the dry and hot summers (July 22 °C) cause high potential evapotranspiration ($\simeq$700 mm) exceeding the annual rainfall (400 – 600 mm) and producing a relatively high moisture deficit (100 – 300 mm). In summer evapotranspiration exceeds rainfall several times; this fact explains the evaporation of a large quantity of water from soils belonging to the areas with shallow groundwaters. As a consequence, there is a slow underground water stream, causing the displacement of soluble salts towards these areas.

As mentioned above, salt accumulation in soils takes place under special local hydrogeological and topographic conditions. The relief units which promote the development of this process in the Romanian Plain are the negative forms of micro- and mezorelief, namely: the lower parts of unfragmented or poorly fragmented interfluves, of old flood-plains, of lower terraces, of old divagation zones, of subsidence plains; the weakly sketched valleys of interfluves or of higher terraces; the gentle slopes of lakes; the low sectors where two relief units are joined (terrace and flood-plain, terrace and plain etc.). To all these units the peripherical parts of piedmont plains or of old alluvial fans may be added [4, 5, 6, 7].

The local hydrogeological conditions — shallow groundwaters with poor drainage or outflow — have the greatest influence on salt accumulation in soils. A close relationship exists between the hydrogeological factors and the above-mentioned relief units; in these areas the groundwaters have a low depth, a very gentle slope and an extremely slow flow, favourable for soil water evaporation; a certain underground salt movement with the groundwater toward the areas with high evapotranspiration is thus promoted causing progressive salt accumulation. The existence of some loam or clay deposits exhibiting good capillary ascension intensifies salt accumulation.

The hydrographic network also influences salt accumulation both by raising the level of the water table in some sectors, and by its lowering in others; salt movements in different directions take place in this way. The fact that the rivers of the north-eastern part of the Romanian plain cross the diapiric folds of the Subcarpathians causes an enrichment in chlorides and sulphates; this explains, to a great extent, the frequent occurence of these salts in groundwaters and soils. To the present action of these rivers must be added their oldest and more intense action dating from the stage when this plain was filled with alluvia carrying small quantities of salts. The redistribution of these salts caused the greatest part of present salt accumulations [4, 5, 6, 7].

In the Romanian Plain two types of salt accumulation were distinguished [6, 7]. They were partially defined according to V. A. Kovda [10]; within these types we may distinguish several migration and salt accumulation mechanisms specific of the local conditions under which the salinization process took place. The knowledge of salt movement and accumulation mechanisms under natural conditions is extremely important from a practical point of view, for the selection of specific hydro-reclamation measures to be adopted in each area; these measures are essential for the desalinization of halomorphic soils as well as for the prevention of secondary salinization which may occur when non-saline soils are irrigated. They are also necessary for the elaboration of a control plan concerning the development of soils and their fertility in reclaimed territories.

The continental-groundwater type, exhibiting salt movement and accumulation through the shallow groundwater, is most frequently encountered in the Romanian plain. This type was divided into two sub-types according to the influence, or the lack of influence of water stagnation (resulting from rainfalls or flooding) on the soil surface. The second type of salt movement and accumulation is the lacustrine one. A brief description of the mechanism of salt movement and accumulation, as well as the reclamation measures necessary for the improvement of hydro-saline soil regime in each case will be presented below.

Five groups exhibiting different mechanisms of salt movement and accumulation were distinguished within the continental-groundwater type, in the subtype characterized by the lack of influence of water stagnation on the soil surface.

1. Depressed areas with shallow groundwater on low plains, terraces, old flood-plains, old divagation zones, located in the subhumid-arid climatic zone, (Fig. 1). As a consequence of high evapotranspiration, the salts from the neighbouring zones will accumulate in these areas. If the depressed areas lie deeper than the medium level of the water table, the formation of lakes takes place; these lakes become salty in time.

The drainage of groundwater through one or more drainage channels according to the extent of the area and to the permeability of the mineral substratum becomes imperative as a reclamation measure permitting soil desalinization in these areas. When placing the channels it is recommended to intercept the water inflow from neighbouring areas, upstream or even in the contact zone with the saliniferous area.

2. Areas close to the contact line between two different types of relief (Fig. 2). In the contact zone between flood-plain and terrace, terrace and plain

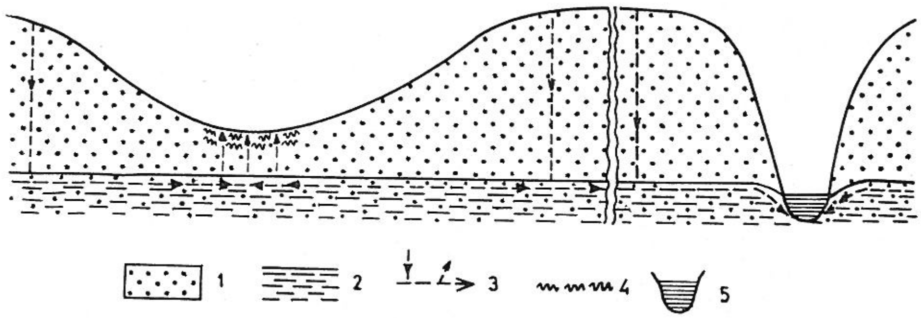


*Fig. 1*
Salt accumulation in depressed areas with shallow water table. 1. Permeable soil and sediment. 2. Water table. 3. Direction of easily soluble salt movement. 4. Accumulation zone of soluble salts in the soil. 5. Salty lake

the groundwaters are often shallow and their movement is slower because in this part of the relief, the finest and less porous sediments are found; under these conditions salt accumulation is speeded up. In this case the control of salt movement and accumulation may be achieved by building a belt channel right under the higher relief unit. This channel will take over some of the water inflow coming from the higher relief unit and lower the water table of the neighbouring area, thus preventing water evaporation from the aquiferous layer, as well as soil salinization.

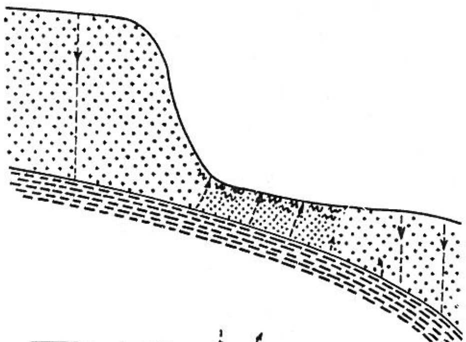


*Fig. 2*
Salt accumulation in areas close to the contact zones between two different steps of relief. 1—4. See: Fig. 1

3. Valleys of poorly drained plains (Figs. 3 and 4). The waters usually flow into these valleys causing salt accumulation and forming halomorphic soils practically all over a narrow valley but only in the lower parts of a wide one.

The reclamation measure recommended in the case of narrow valleys is the building of a drainage channel in the lowest part of the valley to lower the water table; in the case of wide valleys it is proposed to place two main drainage channels along the contact lines between the valley and the plain (or terrace) to stop the water and salt inflow to the valley, and to build at the same time some secondary channels for drainage in the lowest parts of the flood-plain.

4. Periphery of the alluvial fans and the lower parts of unfragmented piedmont plains (Fig. 5). It is known that on the borders of alluvial fans and unfragmented piedmonts where the slope is less accentuated and proluvial, increasingly fine deposits appear, the groundwater rises near the surface of the soil and its flow becomes slower; here water evaporation becomes possible,

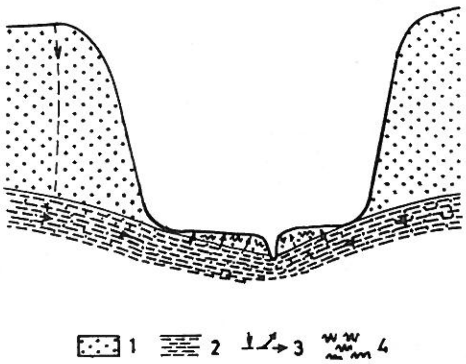


*Fig. 3*
Salt accumulation in narrow valleys located in low-lying, poorly drained plains. 1—4. See: Fig. 1

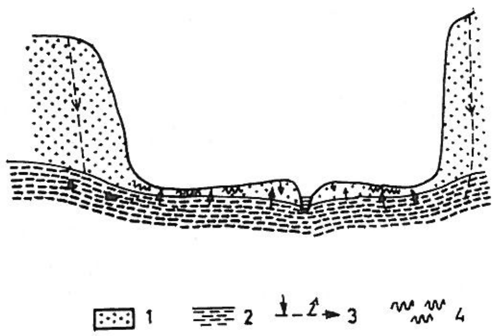


*Fig. 4*
Salt accumulation in large valleys located in low-lying, poorly drained plains. 1—4. See: Fig. 1

bringing about salt accumulation in the soil and in the groundwater, and thus causing an increase of salinity and mineralization.

The reclamation method suggested in this case is to divert the water inflow by a drainage system located right above the areas with saliniferous soils. Drainage may be accomplished through drain channels or draining wells (vertical drainage); vertical drainage may be efficient in this case as the groundwater is usually located in gravels. As the drained waters are only slightly mineralized they may be successfully used for the irrigation of the neighbouring territories. This type of irrigation offers the advantage that it does not essentially change the natural hydrologic balance of the area.

Within the other subtype (characterized by water stagnation on the soil surface) of the continental-groundwater type, two groups were distinguished.

5. Low-lying lands rarely flooded or partially affected by swamping (old flood-plain, old divagation zones, etc.) by surface waters or springs and,

6. Low-lying lands never flooded, without external drainage, partially affected by swamping due to rainfalls (old flood-plains, old divagation zones, etc.), located under subhumid climatic conditions. These cases are shown in Fig. 6. In both groups due to the evaporation of groundwater salt accumulation develops on the tops of banks, ridges or on the higher units of relief located between or around the lower parts which are affected by swamping. The salts originate from the groundwater and, in the first case, from river or spring waters, too.

The control of hydro-saline conditions in the last two cases may be accomplished by drainage channels located on the areas affected by swamping. Nevertheless there exists the hazard of salinization after drainage in the areas previously affected by swamping; to avoid this the drainage system should lower the water table below the critical depth.

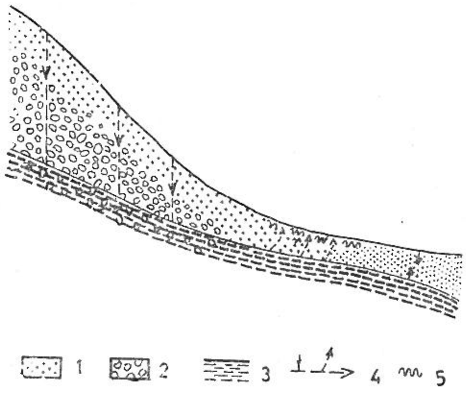

*Fig. 5*
Salt accumulation in the periphery of alluvial fans or in the low-lying parts of unfragmented piedmont plains. 1. Permeable soil and sediment. 2. Psephitic soil. 3. Water table. 4. Direction of easily soluble salt movement. 5. Accumulation zone of easily soluble salts in the soil

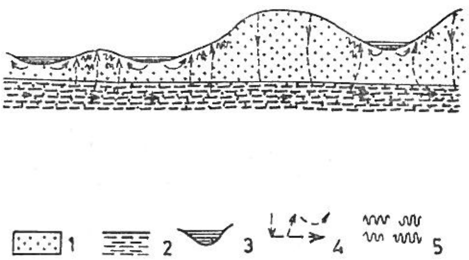

*Fig. 6*
Salt accumulation in low-lying lands partially affected by swamping. 1. Permeable soil and sediment. 2. Water table. 3. Temporary fresh water lakes or swamp. 4. Direction of easily soluble salt movement. 5. Accumulation zone of easily soluble salts in the soil

Within the lacustrine type of salt accumulation the following cases may be distinguished:

7. Areas round fresh water lakes (Fig. 7a). The salts accumulate on the slopes of the lake right above the mean level of lake water, due to both ground- and lake waters.

8. Areas round salty lakes (Fig. 7b). The salts accumulate on the slopes of the lake like in the previous case (here may be added the salt transport by wind "pulverization") and in the bottom sediments of the lake (under the influence of salty waters).

A special case is presented in Fig. 7c; it is the case of the lower zone of some non-salty and salty lakes, in which, under the influence of the hydrostatic pressure, infiltration and then evaporation of water from the lake take place, resulting in salt accumulation.

9. Salty lakes already dried up or under drying. Some salty lakes tend to disappear (due to the drying up of springs) and their water evaporates completely or almost completely; there is water in them only during the rainy years. The salts which were dissolved in the water of these lakes sedimented above the saliniferous mud. Halomorphic soils resulting from the drying up of lakes usually exhibit high salt accumulation, in thick layers.

A modification of the hydro-saline conditions of the salty surfaces located around lakes is difficult; besides, their area is small. For shallow lakes or lakes under drying a drainage channel all around them is recommended as well as a central channel with ramifications sloping towards the more open part of the lake where the water could be pumped out. Sometimes the usually extensive areas with halomorphic soils, located in lower zones downstream the lakes, have to be reclaimed; in this case a drainage channel running parallel to the lake shore, to intercept and take over, in the desired amount, the water percolated from the lake, would prove useful.

It should be emphasized that usually several different mechanisms of salt migration and accumulation in soils and groundwater associate; transitional mechanisms between those described above also exist.

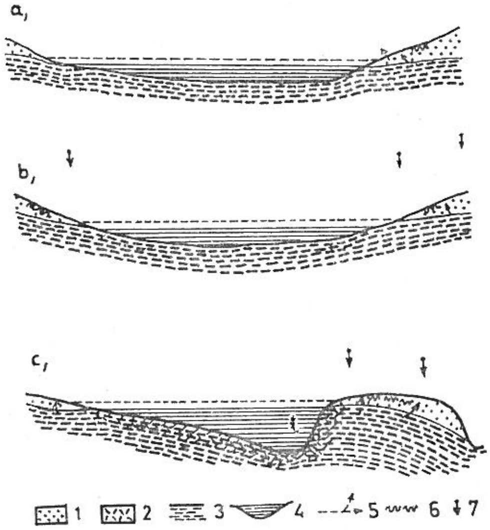


*Fig. 7*

Salt accumulation in areas around lakes and lagoons: *a)* fresh water lakes; *b)* salty lakes; *c)* zones located downstream some lakes and lagoons. 1. Non-salinized sediment. 2. Salinized sediment. 3. Water table. 4. Lake. 5. Direction of easily soluble salt movement. 6. Accumulation zone of easily soluble salts in the soil. 7. Wind driven water drops ("pulverization")

The directions of salt movements through the agency of the groundwater as well as the areas of salt accumulation in the North-Eastern part of the Romanian plain are sketched on the annexed map (Fig. 8). In the West, in the piedmont part of the plain, the movements of salts and slightly mineralized groundwaters are relatively intensive; in the rest of the areas these movements are slower (except in some zones with sandy deposits located on the Northern part of the interfluves); consequently the degree of mineralization of the groundwater as well as the salt content in the lower part of the soil profile, are higher.

In the low-lying part of the plain the rivers also supply the neighbouring territories with salts; this salt supply is very considerable especially on the right side (to the east) of the Buzău, R. Sărat and Rîmna rivers, in the areas where their course changes, and turns towards North-East.

The most extensive areas of salt accumulation are, as indicated on the map, the old river valleys, as well as the depressed areas of divagation zones, the contact zones between terrace and floodplain, the low-lying parts of the piedmont plains, the lowest parts of the interfluves. Lakes with no outflow also represent concentration areas for the inflow of easily soluble salts. It must be emphasized that salt affected areas occur mostly in the axial part of the interfluves and in the transitional zone between the piedmont plain and the plain proper.

In order to assure, without irrigation, the best utilization of lands in the North-Eastern part of the Romanian plain it is necessary to change the natural hydro-saline conditions of the soils at many places, as well as the general salt balance of the whole territory by progressive desalinization.

This can be achieved only by land improvement and reclamation measures promoting and intensifying salt removal through a network of drainage channels. When the outlay of these channels is planned, salt sources and salt circulation, areas and conditions favourable to salt accumulation, as well as the previously described ways and mechanisms of salt migration and accumulation should be taken into careful consideration.

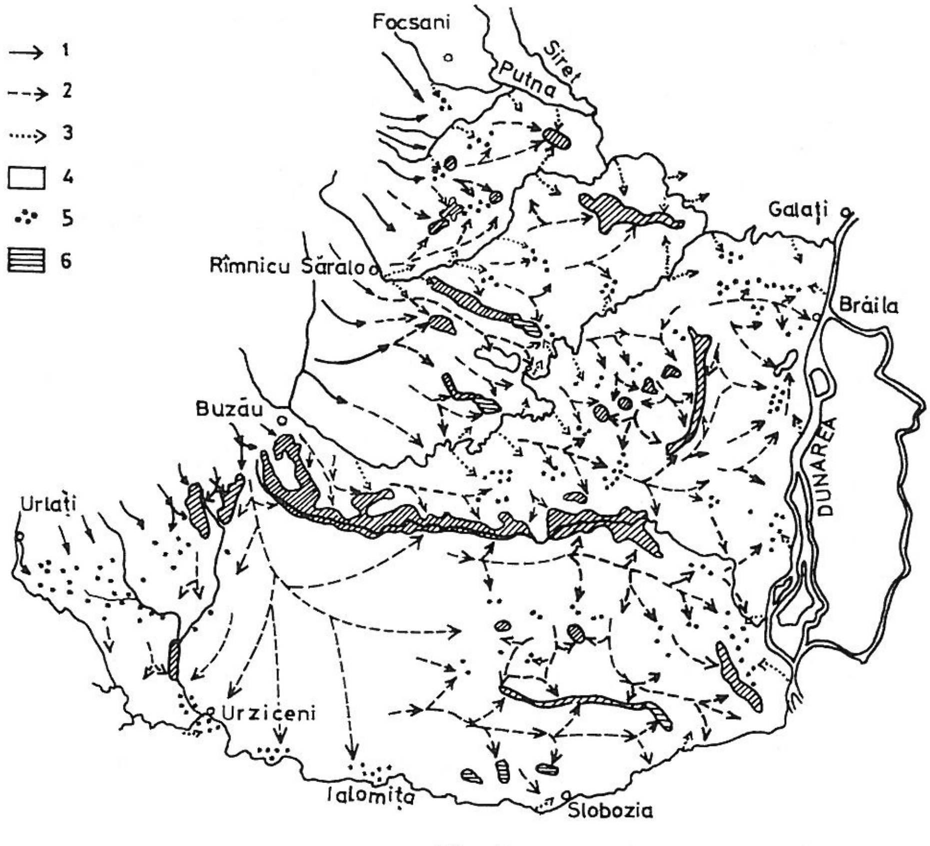


*Fig. 8*

Salt movement in the North-Eastern part of the Romanian plain. 1. Relatively intensive salt movement (with groundwater). 2. Relatively slow salt movement (with groundwater). 3. Movement of salts originating from rivers. 4. Areas exhibiting relatively large salt accumulation. 5. Zone exhibiting relatively reduced salt accumulation. 6. Brackish or salty lakes

The above described conditions of salt accumulation in soils and groundwaters, the mechanisms of the migration and accumulation of salts are not specific to Rumania but actually occur in many other regions of the world under similar conditions. At those places similar reclamation measures may be adopted.

## Summary

Generalization of the data concerning salt accumulation in soils and groundwaters in the Romanian Plain leads to the description of 9 migration and accumulation mechanisms for easily soluble salts in specific conditions (Figs. 1–7). These alternatives concern: 1. depressed areas with shallow groundwater, 2. areas close to the contact line between two relief steps, 3. valleys of poorly drained plains, 4. periphery of the alluvial fans, 5. low-lying lands rarely flooded, 6. low-lying lands never flooded, 7. areas around fresh water lakes, 8. areas around salty lakes and 9. dried up or drying lakes.

The measures necessary in each case for the modification of the hydro-saline conditions and for soil reclamation are described.

The directions of salt movements as well as the areas exposed to salt accumulation in the Romanian Plain are shown on a map.


## References


[1] Conea, A. et al.: Complexul pedologic al văii Călmațuiului. (Pedological characterization of the Calmatui valleys.) D.S. Com. Geol. **46.** 429–443. (1958–1959). 1962.

[2] Conea, A. et al.: Solurile cîmpiei joase a Siretului. (Soils of the low-lying plains of the Siret river.) D. S. Com. Geol. **47.** 421–436. (1959–1960) 1962.

[3] Florea, N.: Adîncimea critică a apei freatice în cîmpia subcolinară Mizil-Stîlpu. (Critical depth of the water table in the Mizil-Stilpu Plain.) Bul. Stiint. Acad., St. biol. agron. geol. si geogr. **6.** (4) 1173–1190. 1951.

[4] Florea, N.: Raionarea preliminară a sărăturilor din R. P. R. (Preliminary territorial grouping of salt affected soils in the Romanian People's Republic.) Probleme agricole, **9.** 48–58. 1958.

[5] Florea, N.: Privire generală asupra sărăturilor din R. P. R. (General review on the salt affected territories of Rumania.) Cerc. Pedol. 251–277. 1961.

[6] Florea, N.: Unele aspecte ale genezei, distribuției și ameliorării solurilor saline și alcalice din Cîmpia Romîna de nord-est. (Data on the genetics, distribution and reclamation of saline and alkaline soils in the north-eastern part of the Romanian Plain.) Publ. Soc. Nat. Romane de St. Sol. **6.** 85–100. 1970.

[7] Florea, N.: Tipurile și mecanismele de acumulare actuală a sărurilor pe teritoriul României. (Salt affected soil types in Rumania and the mechanism of present salt accumulation in them.) Stiința Solului. **8.** (2) 38–54. 1970.

[8] Gustiuc, L., Gheorghiu, E. & Poenescu, M.: Solurile salinizate de pe grindurile fluvio-maritime din Delta Dunării. (Saline soils of the Danube-Delta). Lucr. stiint. Inst. Agr. "Ion Ionescu de la Brad". Iasi. 366–388. 1962.

[9] Ianovici, V. & Florea, N.: Considération sur l'accumulation des sels dans les sols de plaines quaternaires de la Roumanie. Com. Gel. St. techn. si econ. Ser. C. (14) 5–20. 1964.

[10] Kovda, V. A.: Principle of the theory and practice of reclamation and utilization of saline soils in the arid zones. Salinity Problems in the Arid Zones. Proc. Teheran Symp. UNESCO. 201–213. 1961.

[11] Marosi, P.: Raportul hidraulic dintre rîul R. Sărat și apele freatice din zona de contact a subcarpaților cu Cîmpia Romînă. (Relationship between the Sarat river and the level of the water table of the surrounding area at the contact zone between the Romanian Plain and the Carpathian Mountains.) Stud. Univ. Babes-Bolyai. Ser. Geol.-Geogr. Cluj. 33–43. 1963.

[12] Marosi, P.: Originea mineralizării apelor freatice din Cîmpia interfluvială Buzau — Rîn. Sarat. (Origin of the groundwater's mineralization in the interfluve territory at Buzau.) Inst. Geol. Stud. techn. si econ. hidrol. Ser. E. (7) 105–145. 1967.

[13] Obrejanu, Gr., Maianu, Al. & Axenova, I.: Acumularea sărurilor în soluri saline și alcalice din luncile Cîmpiei Române. (Salt accumulation in saline and

alkaline soils occurring on the slopes of the Romanian Plain). Stiința Sol. **2.** (2) 31–40. 1964.
[14] SANDU, GH.: Sursele de săruri in prosele de salinizare și alcalizare a solurilor din lunca Dunării. (Salt sources causing the salinization and alkalinization of soils along the Danube river). ICCA Analele Sect. Pedologie, **34.** 333–345. 1966.
[15] TISON, L. J.: Hydrologie et salinité des eaux souterraines. Salinity Problems in the Arid Zones. Proc. Teheran Symp. UNESCO. 25–36. 1961.
[16] YAALON, H. DAN: Salinisation and salinity. J. Chem. Education. **44.** 591–593. 1937.