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**ALCALI SOILS OF
AZERBAIJAN
AND THEIR
IMPROVEMENT**

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INTRODUCTION

Today, we lay emphasis on raising crop capacity of cultural plants and expanding sowing area. This, in turn, calls for raising fertility of long-used soils and improving fertility of poor soils. Lands in Azerbaijan with poor fertility are salinized or alcali soils. Fertility of these soils is poor, sometimes at zero level. With the objective of applying these soils for agricultural purposes, it is, first of all, essential to improve them radically. For this to happen, it would be appropriate to study reasons of their salinization and identify their properties.

According to acad.L.I.Prasolov and L.P.Rozov's calculations, total area of alcali soils of the USSR is above 40-50 mil.ha. Alcali soils are spread in various areas zones, especially in chestnut, brown and grey zones. Alcali and salinized soils occupy 25-30 mil. ha of chestnut soils; while grey soils occupy about 10 mil.ha area. Soils of this type are also spread in chestnut and grey zones of Azerbaijan. Beyond any doubts, it is essential to improve the type of soils to attain effective results.

As far back as in 1938, Soviet specialists began applying improved soils, largely alcali and salinized soils. It is essential to note that theoretical principles of alcali soils were first explored in the USSR. Contributing to the study of properties and regularities of geographic spreading of salinized lands were followers of V.V.Dokuchayev, founder of the soils sciences, including A.P.Zemyatchenskiy, K.D.Glinka, K.N.Visotskiy, N.A.Dimo, V.R.Volobuev et al.

Proceeding from experimental materials, Russian scientist K.K.Gedroits gave a broad description of properties of salinized soils. In turn, W.R.Williams, basing from physical and chemical principles of Gedroits theory, put forward

biological and biochemical principals to comply with dialectic methods.

For some time past, Azerbaijan soil experts have made their contribution to the research into salinization process and methods of land reclamation.

Contributing to the study of alcali soils scattered across Azerbaijani plains were Soviet researchers S.P.Tuyremnov (1927), S.A.Zakharov (1936), V.V.Akimtsev (1937), H.A.Aliyev (1948), A.S.Preobrazhenskiy (1935), V.R.Volobuev (1938), A.S.Voznesenskiy (1931), Z.G.Zeynalov (1948), etc. However, the above mentioned researchers focused on adequate indices typical for spreading of salinized soils on the explored areas. In some cases alcalinity was established on the basis of high dispersity in the profile of hardened prism-shaped structures; in other cases – on the basis of total quantity of alcalinity or sodium cations in the absorption complex. However, materials available have not yet been thrashed out properly. With that end in view, we consider it necessary to benefit from current materials and the latest facts on the subject. The present work examines regions with alcali soils, conditions of their formation and methods of their improvement.

GEOGRAPHICAL DISTRIBUTION OF ALCALI SOILS AND REASONS OF THEIR FORMATION

Definition of alkali soils

Alkali soils are largely divided into two groups: salinized and alkali soils. As far back as in the end of the 19 century P.A.Zemyatchenskiy (1894) and in the beginning of the 20 century V.S.Bogdan (1900) substantiated the necessity of the division of alkali soils into an independent group. Despite this, subsequently some researchers wrongly confused alkali soils with salinized soils. For instance, K.N.Visotskiy (1900) suggested to divide salinized soils into types as follows:

1. Alkali soils with salts being accumulated on the surface;
2. Iluvial or subsoil alkali with salts deposited at a certain depth.

In turn, P.S.Kossovich (1903-1910) gave his preference to the division of all salinized soils into two groups: alkali and neutral.

Earlier 1920, despite a considerable progress in the development of Russian soil science, D.K.Vilenskiy divided salinized soils into two types: alkali and structure-free and salinized soils.

The division of salinized soils into two groups (saline and alkali soils) is referred to in the works by N.A.Dimo and B.A.Keller dealing with semidesert soils across the world. N.A.Dimo not only distinguished between salinized soils, but also singled out their transition forms and morphology, classified them properly.

In spite of the fact that the former Soviet soils science won leading positions in the world, some agricultural experts confused saline soils and alkali soils genetically terming

them as saline soils. One cannot forget that according to their genetic properties and chemical composition saline soils greatly differed from alcali soils. Despite their unfitness for cultivating agricultural crops, their negative effect on normal development of plants is different. The improvement of these soils is different as well. For this reason, it is crucial to draw proper distinctions between saline soils and alcali soils. A proper definition of these types makes it easier to struggle against salinization of soils and for their proper use.

SALINE SOILS

Soils with strongly salinized surface layers are called saline soils. Quantity of harmful salt is above 3%. In some cases, on the 5-10 cm of surface layer of saline soils the quantity of salts exceeds 5-10%. In this case, the surface layer of the soil is covered with salt or soft salt crust. When walking on soft crust, a man's feet sink in the soil, cars skid. Except for some species, no plants grow on such surface.

As a rule, saline soils emerge on shallow (1-3 m) parts of ground waters. Violation of irrigation methods has an appreciable effect on formation of these soils.

Saline soils are widely spread on steppe, semidesert and desert zones. In Azerbaijan, saline soils are spread in Aghdash, Ujar and Zardab regions of Shirvan plain; Yevlakh, Barda, Aghjabedi regions of Garabagh plain; Sabirabad, Saatli; Ali-Bayramli regions of Mugan plain; Beylagan and Imishli regions of Mil plain; Salyan and Neftchala regions of Salyan plain; plain part of the Nakhchivan Autonomous Republic.

There are following types of saline soils in Azerbaijan: soft saline, saline shell, wet saline, black saline, and hilly saline.

To improve saline soils, it is essential to wash them using collector-drainage network.

In considering that the booklet does not set an aim to provide information about saline soils, we start examining alcali soils.

ALCALI SOILS

Before analyzing reasons of the emergence of alcali soils, it would be appropriate to describe some distinctive features of these soils.

As distinguished from saline soils, alcali soils are notable for absolutely different outward appearance and characteristics. Quantity of soluble salts in the surface layer is very low, sometimes absent. A greater portion of salts in such soils is accumulated in the lower layers. Note that location of soluble salts either in the surface or lower layers of alcali soils is not essential. Quantity of salts in alcali soils, as was the case with saline soils, may be different, either large or insignificant.

A distinctive feature of alcali soils is an excessive quantity of soda, which is very harmful to the normal development of agricultural crops. At the same time, quantity of sodium in the absorbing complex of the soil may be excessive. As a consequence of soda and absorbed sodium's influence, high alkalinity becomes apparent. Alkaline reaction transforms organic matter into soluble humate and thus contributes to the washing of deeper layers. This, in turn, leads to the worsening of physical properties of these soils. For this reason, another distinctive feature of alcali soils is their deteriorated agro-physical properties. Thus, alcali soils have no good structure from agronomic point of view. When dried, these soils are very firm and

lumpy; when wetted, they are sticky and soaked. For this reason, in the course of ploughing related devices and facilities get out of order, consume too much field.

In the course of irrigation, or soon after it, a thick and very firm crust is formed on alcali soils. These properties have a negative effect on the development of agricultural crops, their quantity and quality. As a rule, sprouts on alcali soils appear to be sparse. There is a great quantity of plant-free areas. In many cases, sprouts, especially where crust is hardened, are lost as a result of tearing off. Hardening of the crust leads to the formation of cracks in the soil and rupture of roots.

Layer A of the alcali soils has gray, sometimes whitish color and lamellar. Thickness of this layer is 5-10 cm. Layer B is called a salt layer. Distinctive features of this layer are different from layer A. Layer B has sometimes reddish, sometimes coffee-colored, dark brown color. Structurally, the layer is prism-shaped, some times column-shaped or pedestal-formed. If dried, the layer is very firm, if wet, it is very sticky. The layer is notable for its negative properties, typical for alcali soils. Thickness of the layer is 20-40 cm.

Below the salt layer there is an illuvial layer. The layer is characterized by accumulations of CaCO_3 , CaCO_4 or $2\text{N}_2\text{O}$. Gypsum crystals are found in the form of placers, vein-shaped or fine grains. In some cases, there are also found accumulations of easily soluble salts.

Layer B of the alcali soils is considered to be the most harmful layer for cultivating agricultural crops. Owing to the fact that pillar like structure is very firm and steady, roots of the plants cannot develop properly, so the plants are lost. Depending on the origin of the alcali soils, column-shaped structure of the layer is deep. In this case, plants develop differently, i.e. negative effect of the layer on the plant development is different.

INFLUENCE OF ABSORBED CATIONS ON THE DEVELOPMENT OF PLANTS

An influence of absorbed cations on the development of plants is insufficiently studied. It was K.K.Gedroyts who first studied the problem. As far back as in 1913 he found that after saturation of black soils with cations NH_4 , Na and K the crops are lost if the soil is fertilized by N, P, K and Mg (regardless of CaCO_3). Experiments with Mg-cations also yielded negative results. Despite sprouting of different crops, the harvest is either lost or very meagre. Calcium experiments yielded quite different results. In cases where the absorbing complex was saturated with calcium, no negative results were available; even better, crop capacity sharply increased.

Results obtained by Gedroyts were later confirmed by his collaborator A.T.Kirsanov (1932). The latter showed that the most harmful (toxic) of all the cations were NH_4 and Na. Note that adding Ca- and sometimes H-cations in the soil slightly decreased a negative effect of Mg- and Na-cations.

According to A.T.Kirsanov, influence of metabolic sodium on various types of soil and species of flora is different. His experiments showed that absorbed Na had a negative effect on mustard rather than wild oat. It was established that a negative effect on the development of plants was apparent in cases where the quantity of Na absorbed in the soil reached 15%-20%.

V.A.Kovda (1945) believes that the presence of sodium-silicate, sodium-aluminate, soda and sodium-humate lead to the intensification of harmful influence of metabolic Na-, K- and NH_4 -ions. Y.I.Ratner (1935) showed that sodium-humate demonstrated much greater negative effect.

Kovda, Ratner et al. concluded that harmful properties of the soils soaked with Na-cation absorbed violate normal feeding of plants with calcium.

Hence, rise in the quantity of Na absorbed in the soil has a negative effect of normal development of agricultural crops. This is not to say that Na absorbed in the soil is not needed for normal development of plants. On the contrary, small quantities of this Na are essential. It does not slow down plants' development, instead, speeds it up. Advocating this idea was K.K.Gedroyts, later on Y.I.Ratner, L.P.Rozov et al.

Rozov considers that the plant develops normally when the absorbing capacity of Na absorbed in the soil reaches 5%.

Antipov-Karatayev insists that when the absorbing capacity exceeds 5%, agrophysical properties of the soil are getting essentially worse.

In considering the information as provided by V.A.Kovda (1946), Rozov, Antipov-Karatayev et al., it may safely be conjectured that properties of Na-absorbed are as follows:

1. With the absorbing capacity of Na reaching 3%-5%, favorable conditions for agricultural crops are available.
2. With the figure standing at 5%-10%, agrochemical properties of the soil visibly worsen. To prevent this, appropriate agrotechnical measures (cultivation of the soil) are required.
3. With the figure standing at 10%-20%, high rates of salinization are observed, which, in turn, appreciably deteriorate agrophysical properties of the soil and thus intensify negative physiological influence of metabolic Na. To combat this salinization, chemical improvement is required.
4. With the figure standing at 20%-40%, negative factor of the soil immeasurably increases to reduce its fertility.

GEOGRAPHICAL DISTRIBUTION OF ALKALI SOILS

Alkali soils are usually spread on steppe, semidesert and desert areas. Alkali soils are divided into two groups: steppe and meadow alkali soils.

Note that steppe alkali soils spring up at depths of ground waters below 10-15 metres; meadow alkali soils spring up at depths of ground waters within 2-4 metres,

It would be appropriate to note that salinized soils are mainly spread on steppe, semidesert and desert areas. On the other hand, plain regions of Azerbaijan are largely pertaining to semidesert areas, except for Lenkaran plain. Despite this, the area is not entirely covered with alkali soils. Basic soil types here are brown, gray and meadow soils in parallel with saline soils and alkali soils.

Alkali soils are widely spread on plain areas of Azerbaijan, especially in the north-west of the Caspian littoral, south-east of Gobustan, Salyan plain, south-east of Shirvan plain, west of Shirvan Kur bank, north-west of Garabagh plain, south and north of Mil and Mugan plains. Owing to different physical-geographical conditions and various forms of soil formation in the above-mentioned areas, process of salinization proceeded here differently. For this reason, alkali soils of the republic form on different areas. Thus, it would be appropriate to trace back salinization processes going on the territory of Azerbaijan separately.

HOW ALKALI SOILS ARE FORMED

V.R.Volobuev (1953) singles out four ways of soil formation on Kur-Araz lowland:

1. Eluvial alcalinization resulting from enrichment of soil solutions with sodium cation in terms of soil formation and under the influence of weathering.

2. Alcalinization resulting from poorly salinized surface waters' on influence the soil (under deluvial and washing effect).

3. Alcalinization resulting from the effect of ground waters, preceeding salinization.

4. Alcalinization resulting from the washing (natural or artificial) of salinized soil after the washing (natural or artificial) of salinized soil after the salinization.

Note that V.R.Volobuev failed to properly interpret the alcalinization of Kur-Araz lowland soils. So we consider it necessary to provide more detailed analysis of the subject and refer to another two ways of soil formation.

Eluvial alcalinization

Eluvial alcalinization occurs under the influence of soil formation and weathering in cases where soil solutions are enriched with sodium cations. The nature of eluvial alcalinization is that the process goes back to weathering of bedrock. Resultant alcali soils are primarily spread on watershed portion of locality.

In Azerbaijan eluvial alcalinization is spread on Girovdag watershed in the south-eastern part of Shirvan. Bedrocks located in this area create more favorable conditions for eluvial alcalinization. Thus, mud volcanoes are widely spread in the region. From time to time, these volcanoes spew mud in the environs.

Owing to the fact that the south-eastern part of Shirvan plain was in ancient times located under the sea, there were widely spread sea deposits on Girovdag area. Compositionally, sediments arising from mud volcano eruptions are salty and made of N-cations.

Note that the main soil-formation factor is bedrock in Girovdag. Their weathering occurred under eluvial condi-

ons, i.e. sediments which resulted from weathered bedrock stay where they are formed and thus take a direct participation in soil-formation. In this case, easily soluble salts as main portion of weathered materials have their effect on soil formation.

Analysis of water extract of the reviewed soils demonstrates that the soil has substantially been salinized. In this case, the salinization starts from middle layers of the soil towards lower layers. In the upper part of the soil, salts are insignificant. The below-shown diagram gives a clear idea of what has been said above.

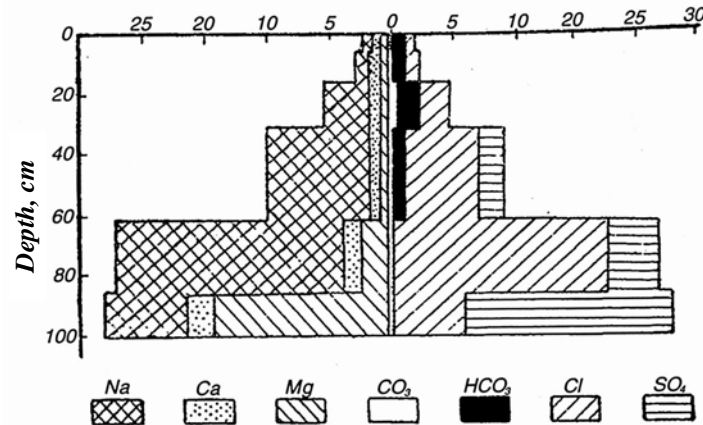


Fig.1. Salinity profile of the soils salinized on eluvial basis, Girovdagh

As is seen from Fig.1, dominating among salts in the soil composition is chlorine anion, and sodium cation. At the same time Na makes up absolute majority in the soil profile, while the quantity of Ca in the 60 cm layer is utterly low. In this case, Na-cation is easily absorbed in the absorbing complex, which leads to the salinization of the soil.

Owing to the fact that eluvial alcalinization occurs simultaneously with soil formation, Na-cation absorbed in

the soil dominates in the upper layers. However, absolute majority usually occurs in the second genetic layer.

In some cases, the quantity of Na-cation in the 1-m layer of the soil which came as a result of the eluvial alcalinization. The quantity of absorbed cations is shown in Table 1.

As is seen from Table 1, the quantity of absorbed cations in various layers of the soil is different. Thus, while the quantity of Ca-cation absorbed in the 0-16 and 62-85 cm layer makes up majority, in other layers its quantity is insignificant as compared with Mg and Na-cations (Fig.2).

The quantity of Ca-cation absorbed in the soil complex in the 5 cm layer makes up both relative and absolute majority. Its quantity sharply decreases as layers go down, it reaches minimum of Ka at depths 16-62 cm; where as absorbed Na-cations forms absolute majority. Note that the quantity of absorbed Mg in this layer is also essential.

The fact that the quantity of Na-cation in the soil makes up 30% and absolute majority is 40-63% in eluvial layer is indicative that the reviewed soil is typical salt alkali soil. An eloquent testimony to the fact is morphological indications in the soil section described by I.Sh.Iskenderov in southwestern part of Girovdagh watershed. Vegetation of the area is largely represented by ephemerals.

The morphological characteristics of the soil is as follows:

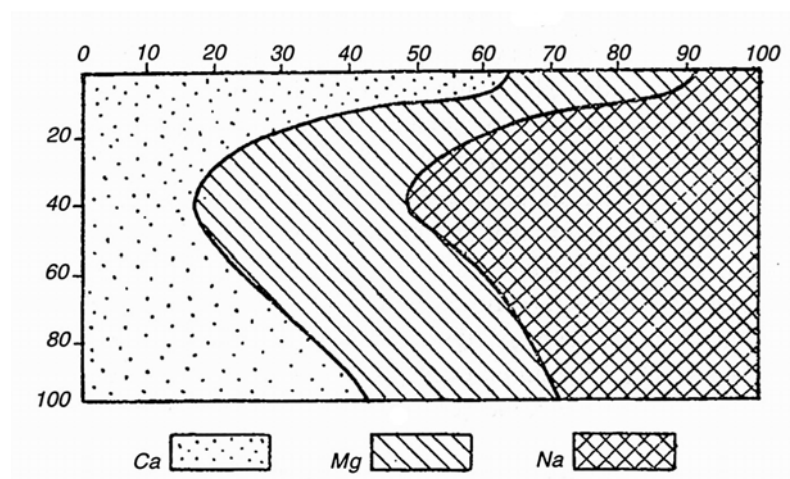


Fig.2. Cations absorbed in alcalized soil on eluvial basis, Girovdagh.

A 0-5 cm – light brown, loamy, hard, dry, transition is clear.

B₁ 5-16 cm – deep brown, hard loamy, prismatic, solid, roots of plants are found in hollows, slightly moist, transition is clear.

BC 37-62 cm – light brown, light loamy structure is not obvious, softish, slightly moist, transition is clear.

C₁ 62-85 cm – brown, light loamy structure is not obvious, softish, slightly moist, transition is clear.

C₂ 85-100 cm – yellowish-brown, without structure, cockle-shells, small grains of crystallic gypsum, slightly moist.

In cases where a comparatively great quantity of humus (2-3%) is placed on 5 cm upper layer, its quantity sharply reduces in the lower layer, hardly reaching 0.5%. Instead, CaCO₃ compound is placed in the upper layer of the soil (8-10%). In the lower layer it makes up 20-25%.

Table 1
Results of the analysis of cations absorbed in the alkali
soil on eluvial basis, south-east of Shirvan (Analysis by
Kovalyova)

Se ction and #	Depth of layers, cm	m.-ekv.			Absorb ed base, total	%			Ca			
		C a	M g	N a		Ca	M g	Na				
Gi rovda g, 39	A ₁ 0-5	9 ,93	4 ,04	1 ,60	15 ,57	0, 199	0, 049	0, 027	63 ,77			
	A ₂ 5-16	6 ,76	5 ,58	6 ,72	19 ,06	0, 135	0, 068	0, 155	35 ,46			
	B ₁ 16- 37	2 ,50	4 ,93	7 ,97	15 ,40	0, 050	0, 060	0, 183	16 ,62			
	B ₂ 37- 62	2 ,92	4 ,61	5 ,04	12 ,57	0, 058	0, 056	0, 116	23 ,22			
	C62-85	2 ,70	2 ,35	2 ,48	7, 53	0, 054	0, 028	0, 057	35 ,85			

Alkali soils formed on deluvial basis

Soils of this type cover broad areas in the republic. These soils are primarily spread in Siyazan-Sumgait massif, south-eastern part of Shirvan plain, south and north-western part of Garabagh, southern part of Mil-steppe, other mountainous regions of the republic. Deluvial flows play an important role in the formation of such soils. When these flows move from foothills to the plain wash out some mechanical materials, various salts and bring them to the plain areas. The composition of the flows is enriched with easily soluble salts and mechanical particles. For this reason, deluvial torrents, when absorbed in the soil, leads to the accumulation of the mentioned materials in the soil.

Owing to the fact that deluvial flows move at different speeds depending on the relief of slopes, they leave behind them different material particles on the affected area. As a result of research work carried out in Girovdag massif, south-east of Shirvan plain, it was established that the speed of deluvial flows on mountain slopes is higher on steep slopes and lower on gentle slopes.

For this reason the speed of the flow is inversely proportional to the speed of water filtering into the soil. Thus, the depth of infiltration of deluvial flows is insignificant on areas with slow speed, while it is great on areas with high speed. An eloquent testimony is Fig.3. It should be noted that substances brought by deluvial flows settle in greater quantity on gentler slopes, and in smaller quantities on steeper slopes. Besides, larger sized particles are piled up on steeper slopes. Smaller particles are carried far away by the flow and lodge on areas where the flow slows its speed down. For this reason the mechanical composition of soils formed on the deluvial slopes is different depending on a specific section of the slope.

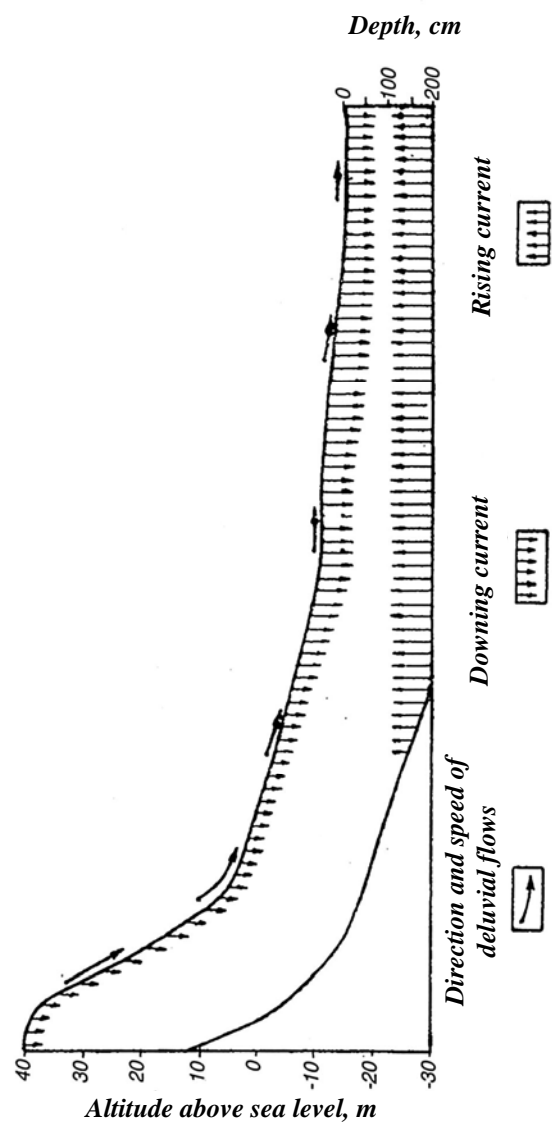


Fig.3. Hydrological zones of alkali soils, which sprang up on deluvial basis in the south-eastern part of Shirvan.

The phenomenon is clearly retraced at Fig.4, Girovdag massif. As is seen, the mechanical composition of the soil is rather light on steeper slopes, and rather hard on gentler slopes. This regularity is also typical for salinization processes. Thus, deluvial flows usually cover its initial part. In this case, the quantity of salts is insignificant and the depth of infiltration is very low, so rates of salinization are relatively low as well. When adjusted for steepness of the slope, deluvial flows are not held back in the soil and begin moving down the slope. It is no mere coincidence that deluvial flows which infiltrated in the soil on steep slopes do not salinize not only upper layers but also wash out salts in its composition and carry them down the slope.

As has been noted above, salinization of the soil on gentler slopes occurs in an opposite direction. Thus, when moving over the surface of the area, the deluvial flows dissolve salts and thus raises condensation of the solution. On the other hand, flows moving inside the upper parts of the slope soil becomes increasingly condensed. In both cases, deluvial flows reduce their speed on gentle parts of the slope and penetrate into the soil. Finally, the solution which penetrated into the soil starts to evaporate at high temperatures and thus contribute to the settling of the salts and their salinization depending on the quantity of the salts accumulated.

Of interest is one aspect of soil alcalinization. As area's altitute above sea level and inclination reduce, ground waters come up to the surface of the soil. In this case, the ground waters prove to be located slightly deeper. Thus, the depth of the ground waters in the lowest part of deluvial slopes is 5-6 m. For this reason ground waters cannot reach upper layers of the soil through capillar ways. The height of the rise covers just 100-120 cm depth of the soil (see Fig.3). In this case the ground waters begin evaporating at the said depth, so salts accumulate in the middle layer of the soil.

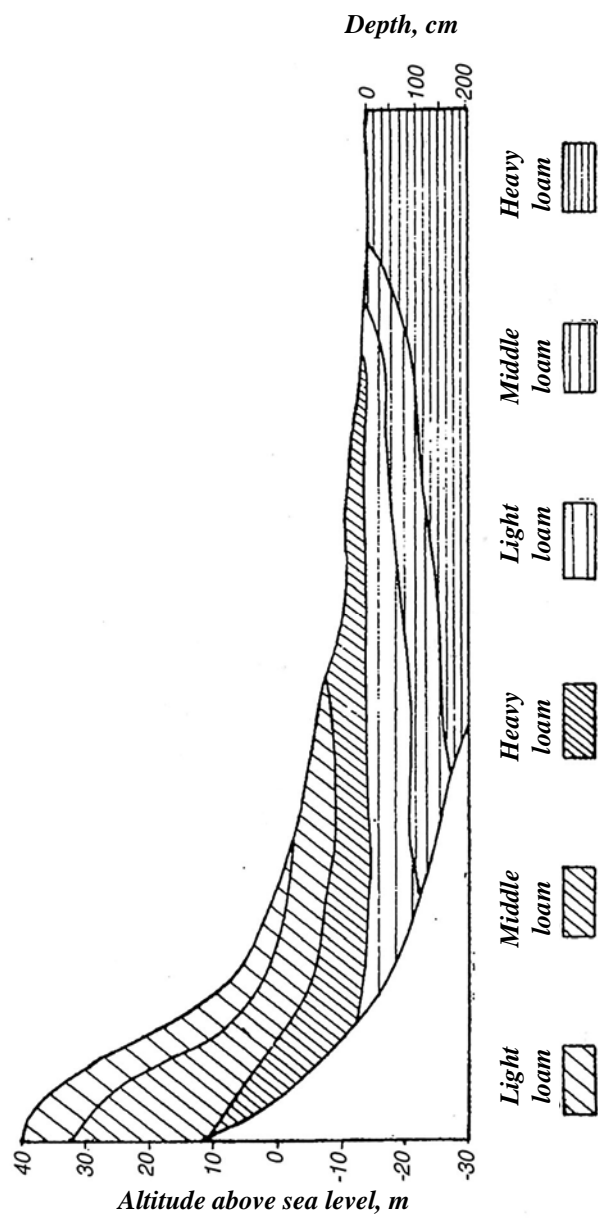


Fig.4. Diagram showing of mechanical content of alkalized soils formed on deluvial basis in Girovdagh massif

On the other hand, deluvial flows pass to the depth on gentler slopes of the area and are accumulated on the upper layer through washing out the salts. It is obvious that middle layer of the soil on lower and gentler slopes is notable for maximum accumulation of salts. The above mentioned is clearly shown at Fig.5.

Depending on the inclination of slopes on either part, deluvial flows are found at different depths and result in salinization of various parts of the soil. In case where the upper layer of the soil on steeper slopes is exposed to insignificant salinization, at deeper layers (50-60 cm) salinization begin intensifying.

Together with rise in total quantity of salts on the middle layers of slopes, thickness of the salinized upper layer of the soil reduces.

Owing to the fact that the quantity of salts spread in the lower parts of slope is great, the thickness of upper layer of the salinized soil reduces to zero. Despite this, quantity of salts in the upper layer of the soil is much lower as compared with the lower layer. In Nakhchivan, we see the opposite picture. All these are more typical for deluvial slopes.

As is seen from Fig.6, on all the parts of the slopes of Girovdagh massif the soils are salinized with NaCl. In the meanwhile, the quantity of Ca and Mg is much lower. In all cases, the quantity of Na-cation exceeds other cations in the soil profile. This is explained by the fact that waters which form sources of deluvial flows in the reviewed area are largely salinized by NaCl. In this case, total quantity of salts in deluvial flows is 1.465% of Ca+Mg ions, while Cl-ions form half of total quantity of salts, and Na-ions – above 23. Total quantity of salts per litre is above 20 gr (see Table 2).

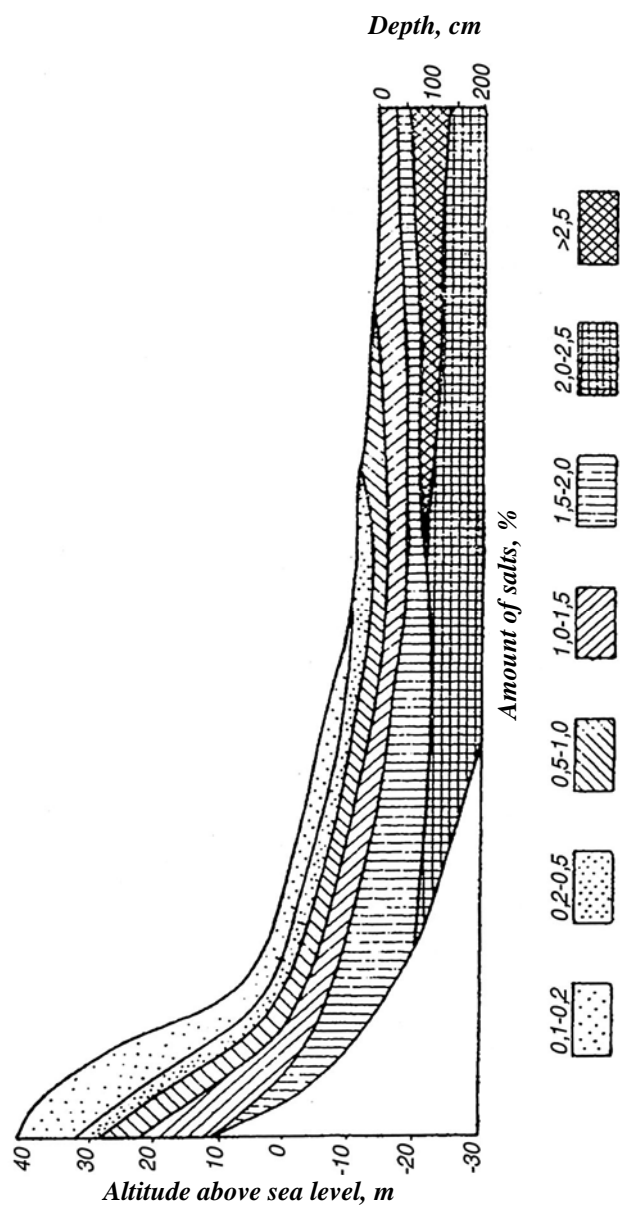


Fig.5. Degrees of salinization of alkali soils on the deluvial basis, Girovdagh massif

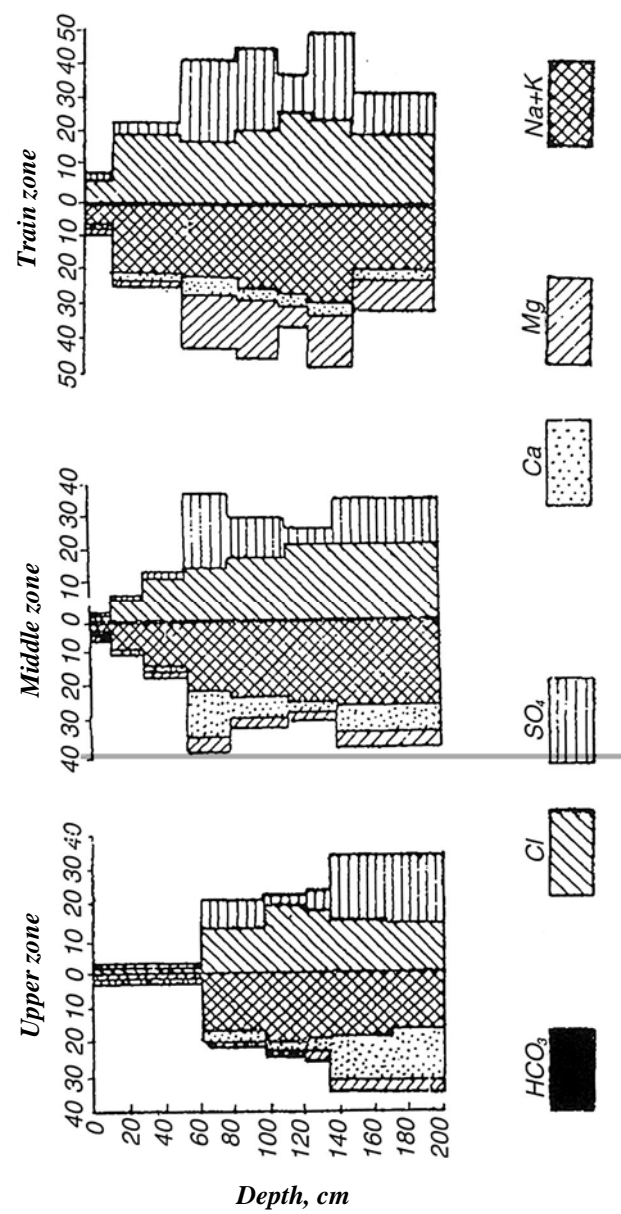


Fig.6. Salt profiles of alcalinized soils on the deluvial basis, Girovdagh massif

Table 2.

**Results of the analysis of gryphon waters spread at
sources of deluvial flows**

Place and data of samples	Dry residue	Salts, total	HCO ₃	Cl	SO ₄	Ca	Mg	Na+K
Girovdagh 9.III.57	21,056	20,977	0,113 1,84	12,040 339,43	0,112 2,33	1,289 14,40	0,175 14,40	7,248 315,15

When Na-cations, contained in the composition of salts of deluvial flows, penetrate into absorbing complex of the soil, there occurs alcalinization. Of greater importance is the movement of deluvial flows, absorbed in the soil, towards lower parts of the slope. On the one hand, deluvial flows wash out salts in the soil and bedrock, on the other hand, result in raising Ca-cation in the absorbing complex of the same soil. Thus, Na-cation passes over to the absorbing complex of the soil and gradually makes the soil alcalinized and, hence, unfit for cultivation.

To describe alcalinized soils affected by deluvial flows, it is essential to characterize soils spread in the middle zone of deluvial slopes of Shirvan plain.

The soil section is located in the broader part of the plain of gentler slopes of Girovdagh massif. Vegetation cover is largely composed of wormwood.

Layer A (0.14 cm) has solid, average clay and clearly prism-shaped structure. Note that prism-shaped structures are divided into separate layers. Parts of these structures are covered with roots of plants.

Structure of layer B (14-56 cm) is pillarlike. By its density the said layer is very firm, so roots of plants could not penetrate it. Pillarlike structure is separated by wide cracks. Roots of plants can move across these cracks only. At the same time, mechanical composition of this layer is much heavier than layer A. Thus, the quantity of physical

clay in the layer B exceeds 80%. Softened as Ca carbonate, layer S is characterized by accumulation of gypsum, in the form of separate granules. Mechanical composition of the layer is a mean clay, the quantity of physical clay is 70%-75%. The structure remains unclear. As diameter of cracks in the layer S gets narrower, their quantity reduces as well. There are distinct transitions between some genetic layers.

As is seen from the above-stated, these are typical alkali soils by their morphological properties.

Analysis of micro-aggregate composition of soils reaffirm their alcalinization. As is known, micro-aggregate composition of soils is a major factor that determines their structure. Let's assume N.A.Kachinskiy's (1943) "dispersity factor" as a basis. Under "despersity factor" (K) is meant a ratio (b) of silt particles percentage obtained as a result obtained as a result of micro-aggregate analysis:

$$K = \frac{a \cdot 100}{b}$$

As is seen from Table 3, percentage of "dispersity factor" is 59.6% to 71.0%.

Table 3.

Microaggregate composition of alcalinized soils on the deluvial basis, Girovdagh massif

Depth, cm	1.0-0.25 mm	0.25-0.05 mm	Quantity of fractions, %					Dispersity factor, %
			0.05 mm-0.01 mm	0.01 mm-0.005 mm	0.005 mm-0.001 mm	<0.001 mm	<0.01 mm	
0-10	0.8	1.7	24.7	10.3	18.5	44.0	72.85	59.6
10-25	0.1	2.9	23.5	8.5	22.0	43.0	73.5	71.0
25-50	0.1	4.9	23.8	18.6	34.6	34.6	71.2	
50-75	0.6	13.4	10.0	33.0	29.5	13.5	76.0	45.0
75-100	0.6	6.9	22.5	15.5	36.5	18.0	70.0	48.4
100-125	1.2	14.8	22.0	13.0	30.0	19.0	62.0	30.3
125-150	1.1	13.9	18.5	13.0	35.0	18.5	66.5	44.6
150-175	1.2	11.3	17.5	16.0	33.4	20.6	70.0	50.6

Analysis of bases in the soil shows that in layer A the quantity of sodium absorbed forms just 5% of based absorbed, while in layer B the figure exceeds 10-24%. As is seen from Tables 4 and 7, in the absorbing complex of the soil predominating are Sa-cation and Mg absorbed. Despite this, the large quantity of Na-cation absorbed in layer V is indicative of alcalinization of these soils.

Table 4.

Results of the analysis of cations absorbed in the alcalinized soils on the deluvial basis, Girovdag massif

Depth, cm	Ekv.			%			Total, %		
	Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na
A 0-14	10.96	4.26	0.8	0.220	0.052	0.018	68.42	26.59	4.99
B ₁ 14-31	8.90	4.81	1.6	0.178	0.037	0.037	58.13	31.42	10.45
B ₂ 31-56	6.84	3.68	3.4	0.137	0.088	0.088	49.14	26.44	24.12

On gentler parts of slopes, the alcalinization process is more pronounced. However, accumulation of salts easily soluble in the soil has its effect on weakening of morphological components on weakening of morphological components in the profile of the reviewed soil.

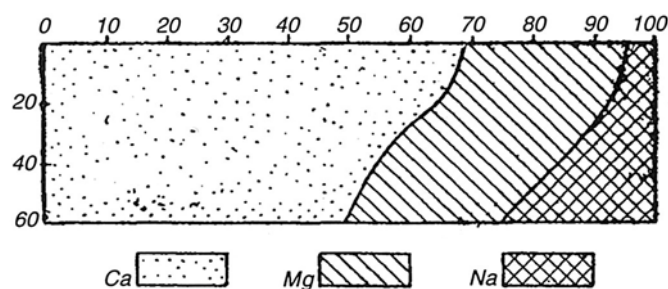


Fig.7. Profile of the quantity of cations absorbed in the alcalinized soil on the deluvial basis.

Alcalinization that precedes salinization

It was primarily V.A.Kovda (1946) who described alcalinization process that precedes salinization.

Owing to the decline of erosion basis, a connection between the upper layer and the ground waters is interrupted. This is attributable to the drop of the ground waters level. Two factors are typical for steppe and desert zones' soil within a year:

1. In winter-spring time the soil is exposed to washing under the effect of atmospheric precipitation.

2. Water absorbed in the soil in interspring time begins evaporating in summer-autumn time and reaches upper layers of the soil with salts dissolved.

In the first instance, in winter-spring time, surface waters which come as a result of precipitation and over-flooding of rivers contribute to the rise in the level of poorly salinized ground waters. Then, poorly salinized ground waters begin evaporating in summer-autumn time and discharging salts on upper layers of the soil. For this reason, despite insignificant or zero salinization of the reviewed soil, the salts stored in the soil are shaped as saline profile, i.e. maximum quantity of the salts is accumulated in the upper layer of the soil (Fig.8). Salts on the surface of the soil, under the effect of precipitation in winter-spring time, are rewashed into the lower layers.

It should be noted that most actively involved in the process is NaCl salt. Owing to the fact that this salt is easily soluble and transferable, it takes part in migration and washing-out processes. As a result of centuries-long process Na-cation penetrates into the absorbing complex of the soil and pushes absorbed Sa-cation out of the soil. Thus, Sa-cation joins SO₄-cation and is stored in the lower parts of the soil in the form of gypsum crystals. As a result, the soil is

exposed to alcalinization ignoring the salinization effect. For this reason, these soils are called alcalinized soils before being salinized.

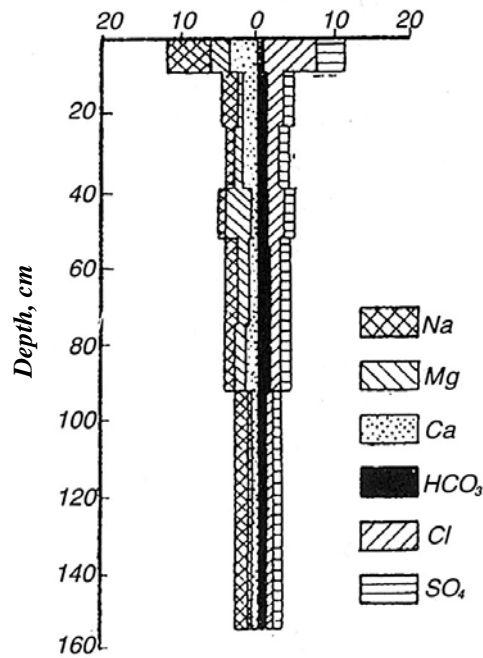


Fig. 8. Salt profile of alcalinized soils preceding salinization

Owing to changes in physical-geographical conditions of the area, rise in erosion basis leads to raising the level of ground waters. Proximity of the level of ground waters to the upper layer of the soil accounts for their evaporation in hot season and subsequent salinization. Thus, previously unsalinized alcali soils assume a new property, i.e. alcalinization. Let's retrace the alcalinization process in the alcalinized soils.

Alcalinization of soils under the effect of salinization process

As has been noted above, easily soluble salts are ordinarily concentrated in the lower parts of alkali soils. Sometimes, these salts are absent or found in tiny quantity. However, there are cases where salts are scattered in great quantities across the profile of alkali soils. These soils are termed “saline alkali soils”. It would be appropriate in this case to give a more detailed explanation on the subject.

As a rule, saline-alkali soils are spread in the lower part of ground waters. Under natural conditions, ground waters are accumulated on the train area of steep sections of the relief. In this case, the salinization of ground waters is high. This is accounted for by the fact that when ground waters reach lower parts of the area a portion of it rises to the surface and begins evaporating; as a result, a great quantity of salt is piled up in the soil layer. In doing so, density of ground waters increases.

On the one hand, in the course of flowing ground waters dissolve a portion salts in the soil and earth. As has been noted above, sodium salts dominate in ground waters. The evaporation of ground waters in the said zone leads to salinization of the soil and, as a result, ends with their transformation into saline soils. On the other hand, Na-cation predominates in ground waters and its joining chlorine compounds makes it more mobile. Na-cation plays a decisive role in the salinization process enriching the soil with the said cations. As a result, Na-cation transfers to the absorbing complex of the soil and thus alkalinizes it. The alcalinized soil is morphologically different from alkali soils. Thus, there are obviously pronounced pillarlike forms of the structure of alkali soils; on the other hand, an identical structure does not manifest itself so clearly on saline-alkali soils. This is

accounted for by the fact that a great quantity of salts easily splits clods and thus destroys the structure components.

To get a clear idea of the situation, it would be appropriate to describe specific features of saline alkali soils spread on Shirvan plain.

A section that clearly characterizes saline-alkali soils is located in Ujar region. According to the microrelief, there are shallow depressions and not high eminences on the locality alternately with various bushes and ephemerals. The surface of the earth is split into clefts with widths reaching 3 cm in the upper part. Note that ground waters are bedded at the depth of 4-5 m.

Sh.H.Tahirov's analysis shows that the surface of the soils is notable for thin coating. From the upper part and to depths of 10-15 cm the structure gets cloty; at depths of 100 cm the structure is cracks in the soil profile go down to depths of 20-30 cm, then their width gets narrower in the lower layers.

Mechanical composition of the 20 cm upper layer of the saline-alkali soils is hard clay. As it goes downwards its composition gets lighter. In the upper layer, silt particles are numerous (45%); in the lower layer – insignificant.

According to N.A.Kachinskiy's classification, the mechanical composition of the reviewed soils belongs to silt-dust group.

The fact that the specific weight of eluvial layer is higher as compared with other layers (1.53-1.64) once again confirms that the soil is alcalinized.

Ca-cation, absorbed in the absorbing complex of the soil forms majority in all the profiles. Its quantity is 47.8%-75.88% of absorbed bases. Absorbed Mg-cation dominates in the 6 cm upper layer (15,3%-18,4%). In general, the cation makes up 10,2%-18,4% in the total absorbed bases.

Table 5
Quantity of cations absorbed in saline-alkali soils of
Western Shirvan plain

Depth, cm	%			m.-ekv.			Absorb ed bases, total m.-ekv			
	Ca	M g	Na	Ca	M g	Na				
0-1	0.1 42	0.0 3	0.1 15	7.0 7	2. 72	5. 00	14.79	:		
1-6	0.1 66	0.0 28	0.1 03	8.2 9	2. 32	4. 50	15.11	:		
6-19	0.3 06	0.0 32	0.1 17	15. 30	2. 60	5. 10	23.00	:		
19-44	0.2 51	0.0 24	0.1 08	12. 50	1. 95	4. 70	19.15	:		
44-64	0.3 92	0.0 33	0.0 75	19. 97	2. 73	3. 30	25.00	:		
64-89	0.2 59	0.0 32	0.1 15	12. 92	2. 60	5. 00	20.52	:		
89-124	0.3 77	0.0 40	0.1 15	18. 79	3. 30	5. 00	27.10	:		

Note that the quantity of Na-cation absorbed in the soil is rather large and distributed unevenly in the soil profile. Thus, the said cation makes up 13,2%-33,8% (Table 5) of total bases absorbed in all the profiles, while maximum quantity is concentrated in 45 cm upper layer. Its quantity makes up 22,2%-33,8% of total bases absorbed in the said thickness. Its quantity is much lower in the lower layer of the soil (except for 64-89 cm).

The above-mentioned is an eloquent testimony to the fact that the reviewed soils are alcalinized.

Salinity of the soil is rather high, it is pronounced in its upper layer. Quantity of salts in this layer exceeds 10%. Quantity of salts in the lower layer being rather high notwithstanding (2.6%-4.3%), they form relative minority in the said layer.

As for anions in the soil profile, SO_4 is dominant here. However, Cl-anion being lower in quantity as compared with SO_4 notwithstanding, they are dominant in the soil profile. As for cations, Na is dominant here. Quantity of this cation, especially in the upper layer of the soil, is rather great. Total quantity of Na- and K-cations in 0.5 m layer is about 1%; in the second 0.5 m layer is comparatively low. However, deeper than 1 m the quantity essentially rises.

Quantity of Mg-cation in the soil profile is very low. As compared with Mg-cation, quantity of Ca-cation is higher. Despite this, its quantity is unlikely to reach Na+K-cations. These indices show salinization of the soil with Na_2SO_4 and NaCl salts.

Alcalinization of soils due to washing out of salinized soils

Alcalinization of soils on account of washing out of salinized soils out occurs in two ways: natural washing-out and artificial, or land-reclamation one.

Alcalinization of soils in consequence of natural washing out. It was acad.K.K.Gedroyts (1953) who first explained the formation of alcali soils through natural washing out. In particular, he proved that alcali soils came as a result of predominating positions of Na-cation in the absorbing complex.

By the absorbing complex of soils we mean the ability of soils to absorb and store dissolved and suspended in the solution halogens and related gases. Contributing to the absorbing process are basically 7 cations – H, Na, K, Mg, Ca, Al and Fe. Of them, Al-, Fe, and K-cations are rarely absorbed in the soil. However, Ca⁰, Mg-, H- and Na-cations, particularly Ca- and Mg-, are considered to be the most active in the absorbing process. Absorbing ability of the seven cations is especially pronounced in specific soil areas. For instance, owing to the fact that no water soluble Ca and Mg are available in the podzol soils and that strong washing-out processes occurring there, no cations of Ca and Mg are found in the area. In the meanwhile, H-ion dominates in the absorption of these soils.

Owing to the fact that bedrock which form soils in the steppe zone are largely composed of loess sediments, the absorbing complex of these soils is saturated with Ca- and Mg-cations. At the same time, Ca- and Mg-cations prevent univalent cations from penetrating into the absorbing complex of the soil.

The dry and hot climate of desert and semidesert zones is a reason of the accumulation of salts, easily soluble in the soil. The quantity of the salts of Ca, Mg compounds is insignificant; that of Na compounds is essential. For this reason, Ca-and Mg-cations, which do not dominate in the soil, cannot displace univalent cations, especially Na-cations, in the absorbing complex. As a result, together with Ca- and Mg-cations, that of Na also forms majority in the absorbing

complex. This is explained as being due to the fact that the climate of desert and semidesert zones is dry and hot and, hence, ground waters here are mainly salty. Note that bedrocks involved in soil forming are made of sea sediments. For this reason, the above-cited factors account for essential salinization of soils. Besides, ground waters of the reviewed area are shallow and in hot time they easily go up and begin evaporating.

This process lasts long and results in salinization of the soil profile and formation of saline soils.

Owing to the fact that saline soils are primarily saturated with NaCl, Na₂SO₄, CaCl₂, CaCO₃, CaSO₄ salts, and for this reason Na- and Ca-cations dominate there. Of them NaCl and Na₂SO₄ are easily soluble in water. Despite this, the quantity of CaCl₂ salt is insignificant.

The quantity of CaSO₄ and CaCO₃ salts in the soil may be great. However, CaSO₄ salt is hardly soluble in the water. On the other hand, the fact that NaSO₄ salt having anion identical to gypsum anion (SO₄) means that gypsum (CaSO₄) solubility degree somewhat reduces. Owing to the fact that CaCO₃ salt is hardly soluble in the water, Ca-cation is tiny in the soil solution. Thus, NaCl and Na₂SO₄ salts dominate in soil salinization. It is obvious that Na-cation takes a dominant position in salinized soils as compared with other cations. Therefore, salts easily soluble in the water during the washing out process, are washed down lower layers of salinized soils. As is known, Na-cation is dominant in the soil profile, so it may easily penetrate into the absorbing complex of the soil and thus contribute to the alcalinization of the soil.

Touching upon natural washing-out occurring in desert and semidesert zones, we do not mean the washing-out process in absolute terms. It is understood in relative terms only. Thus, it would be out of place here to speak about washing-out process in absolute terms when adjusted for

insignificant precipitation and strong evaporation typical for the said zones. Despite this, the role of natural washing-out in the alcalinization of the zones' soil is crucial. Thus, negligible precipitation notwithstanding, its greater portion falls on autumn-winter time and earlier spring. Owing to low temperatures in this season, an unimportant part of the rainfall is exposed to evaporation, while the rest is absorbed by the soil. In this connection, salts located on the upper part of the soil are gradually washed out and piled up in the lower layers and, thus, the upper part is cleaned from salts. As for spring-summer time where surroundings are irrigated, the level of ground waters sharply rises and under the effect of high temperatures waters go up to the surface via capillaries (like kerosene moving up in an oil lamp) and begin evaporating. In doing so, ground waters store up sodium salts (these waters are salinized with sodium compounds) and thus resalinize the soil. In the course of natural washing-out and salinization the salts are exposed to permanent circulation, and as a consequence the absorbing complex of the soil gets saturated with Na-cation.

The quantity of Na-cation in the absorbing complex of the soil is largely dependent on the composition of saline soils being washed out. Where sodium salts predominate, the quantity of the same cations in the absorbing complex is large as well. Where there are salts of Ca and Mg, along with these of Na, the same cations (Ca in the absorbing complex of the soil and Mg) are also available. Besides, the washing-out process in desert and semidesert areas may occur in a different manner as well.

As is known, ground waters are notable for their specific flowing rate depending upon the surface structure and mechanical composition of the soil. In this case, ground waters flow from steeper to gentler slopes and wash out salts it collides with and thus affects removing Ca- and Mg-

cations from the absorbing complex (because of Na-ion in its composition). As a result, Ca- and Mg-cations go out of the absorbing complex and enable Na-cation to fill in the gap. Thus, the soil being exposed to alcalinization loses its original properties and assumes the new ones.

It would be appropriate to briefly characterize two types of alcali soils on Mugan plain.

Figures shown in Table 6 are pertaining to samples of alcali soils spread in the central part of Mugan plain. As is seen from Table 6, Ca absorbed in the soil profile, is prevailing. It is more typical for the upper part of the soil. Its quantity in the lower part is as less as twice. However, the quantity of Ca absorbed in 75-115 cm layer of 10-E section exceeds that of all remaining layers taken separately.

Quantity of Mg absorbed is essentially down from Ca absorbed in the two soil profiles. However, Mg absorbed in 30-39 cm layer of 40 section exceeds that of Ca absorbed.

Of interest are regularities of Na spreading in the profile of soils. Fig. 9 provides a clear picture about the spreading. As is seen from Fig.9, the quantity of sodium absorbed in the upper and lower layers of the section is comparatively small. Maximum quantity of sodium absorbed is concentrated in the alcalinized layers of the both sections. Thus, the quantity of Na absorbed in 12-66 cm layer of 40 section being considerable its quantity in 13-39 cm layer is much greater. The fact that total quantity of cations absorbed in the said layer is above 30% confirms once again that the soil is a typical alcali soil.

Section 10 E is notable for increased quantity of sodium absorbed in the alcali soil, which came as result of washing.

Table 6
Quantity of cations absorbed in alcali soils, which arose as a
result of natural washing, Central Mugan plain

Section	Depth, cm	m.- ekv.			m.-ekv., total	%					
		Ca	M g	N a		Ca	M g	N a	Ca		
4 0	0-4	12. 76	5 .01	0. 64	1 8.41	0.2 56	0. 061	0. 015	69. 31		
	4-12	11. 21	8 .01	1. 44	2 0.66	0.2 95	0. 097	0. 033	54. 25		
	12-17	9.0 7	8 .49	3. 12	2 0.68	0.1 82	0. 103	0. 072	43. 85		
	17-30	7.5 8	6 .17	6. 08	1 9.23	1.1 52	0. 075	0. 140	39. 15		
	30-39	6.4 1	8 .04	6. 38	2 0.83	1.1 28	0. 098	0. 147	30. 77		
	39-66	6.0 9	4 .39	2. 24	1 2.72	0.1 22	0. 053	0. 052	47. 87		
1 0 E	0-12	15. 96	6 .17	2. 32	2 4.45	0.3 19	0. 075	0. 053	65. 28		
	12-20	7.8 3	7 .47	1 2.24	2 7.54	0.1 57	0. 098	0. 282	28. 43		
	20-44	4.2 2	5 .66	1 7.84	2 8.72	0.0 84	0. 053	0. 410	14. 69		
	44-75	Gyp sum	-	-	-	Gyp sum	-	-	Gyp sum		
	75- 115	25. 13	7 .31	0. 72	3 3.16	0.5 04	0. 089	0. 016	75. 78		

Quantity of Na-cations absorbed in 12-44 cm salt layer exceeds 44-62%, which is more typical for alkali soils spread on Mugan plain.

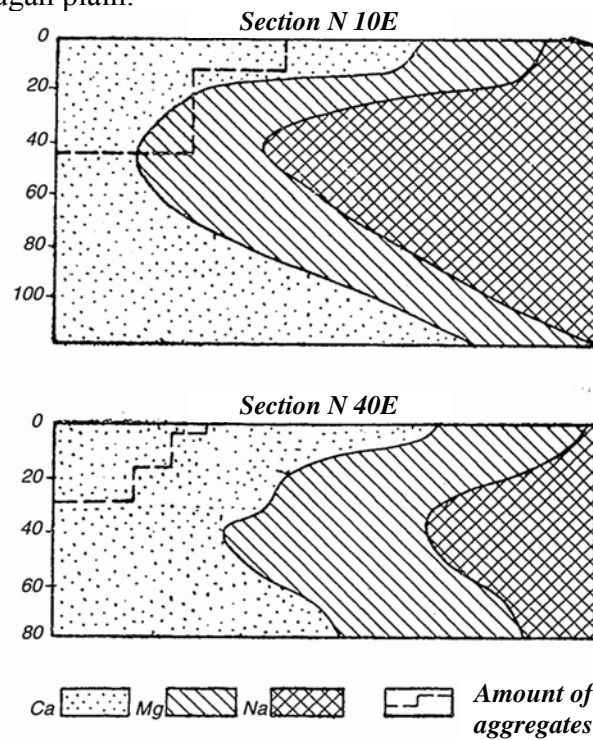


Fig.9 Cations absorbed in alkali soils which came as a result of natural washing-out in Central Mugan

The quantity of Na-cation absorbed in both layers tends toward rise in the middle layer and affects aggregate state of the soil. As is known, increased quantities of Na have a negative effect on aggregation of the soil. Increased quantities of Na in both sections (40 and 10 E), especially in alcalinized portion of the layer, resulted in disturbing aggregate state of the soil. As is seen from Fig.10, aggregation manifests itself poorly in the alcalinized portion of the layer.

There is no essential difference between natural and artificial washings-out. The only difference is in washing-out being natural or artificial. Thus, while under natural conditions the washing-out process proceeds under the effect of atmospheric precipitation, under artificial conditions it proceeds under the effect of land-reclamation actions. In this case, salts, stored in great quantities in the upper layer of the soil, are washed out under the sheet of water into lower parts of the soil together with Na-cations and thus alkalinize it. A distinctive feature of artificially formed alkali soils is that in the course of washing-out there spring up sodium bicarbonate and sodium carbonate salts. This largely occurs at the expense of CO_3 and HCO_3 -ions increase in the soil.

As a result of field work done on the south-eastern part of Shirvan plain, it was established that while there are no CO_3 -ions in the saline soil before the washing-out, the quantity of HCO_3 -ions is insignificant. Meanwhile, the soil being washed out under increased sheet of water (8,000-12,000 m^3 per ha) there come up the first ion (CO_3), and the quantity of the second ion (HCO_3) sharply rises from 0.024%-0.134% to 0.117%-0.171%.

This explains the formation of CO_3 -ion and rise in the quantity of HCO_3 -ion. Owing to the fact that the soil is primarily salinized with NaCl, Na_2SO_4 salts, Na is absorbed, Cl- or SO_4 -ions go out of the absorbing complex and join Ca, thus, forming CaCl_2 or CaSO_4 thickened solutions. Because of the soil solution being thickened after the first washing-out (at the expense of dissolved salts), Na absorbed in the soil cannot go out of the absorbing complex, so soda does not emerge in the solution.

Decline in the soil condensation due to the salts being washed out in the subsequent washing-out leads to the removal of Na absorbed and results in alkalinity formation in accordance with the formula shown below:

(Soil). NA – NAON – NaHCO_3 – Na_2CO_3

Following the results of experiments carried out by K.Gedroyts in 1912-1913, it was established that if washed out several times the quantity of soda in the soil gradually increases; if washed out subsequently the same quantity gradually decreases and finally comes to naught. An eloquent testimony to the fact are indices as shown in Table 7.

Table 7

Soda dynamics in the course of washing-out

Washing-out, #	1	2	3	4	5	6	7	8	9	10
Quantity of soda, %	0.0	0.01	0.08	0.018	0.006	0.006	0.004	0.004	0.00	0.0

Following the results of large-scale experiments, L.P.Rozov (1956) came to the conclusion that 1) alkalinity manifests itself after main portions of easily soluble salts are washed out; 2) this is attributable to the sharp rise in dispersity of soil particles, increase of alkalinity and split of the absorbing complex (emergence of SiO_2); 3) the greater the salinization before the washing out, the more apparent the alkalinity of the soil is; 4) alkalinity resulting from the 2-3 washings comes to naught in the course of 5-6 washings (this is apparent in the land-reclamation effect of CaCO_3 compound).

Thus, it may safely be conjectured that alkalinity as a consequence of land-reclamation washing processes may be removed unless the washing process is over. In this case, huge quantities additional working force is necessary. Finally, owing to the destruction of the absorbing complex (malting¹) the soil

¹ Malt soils come up as a result of malting. These are soils which emerge as a result of changes in alcali soils under natural conditions.

gains other properties and becomes unfit for cultivation. It would be inappropriate to carry on washing procedures after the washing of harmful salts (L.P.Rozov, 1956).

It would be advisable to identify methods of washing to be used in the irrigation of agricultural crops.

If there are Na salts in the irrigation water, Ca-cation in the absorbing complex is replaced by Na-cation. This time, Ca-cation, displaced from the absorbing complex, joins Cl- or SO₄-anions and concentrates in the lower layers or ground waters, so roots of plants are exposed to alcalinization.

This is typical for non-carbonate soils if irrigated by salt waters. Some researchers (V.Kelly et al) showed that agricultural crops cannot be irrigated to comply with 1:1 Na/Ca+Mg ratio. Should ratio exceed 2, an appreciable alcalinization would occur.

Carbonate soils drag out sodium absorption. According to observations of I.V.Ivanova and A.N.Rozanova, Na+K/Ca+Vg ratio in the irrigation water being less than 1, there is no risk of alcalinization if trying to irrigate sowing areas with this water. If ratio ranges between 1 and 4, there is weak alcalinization in the soil; if above 4, alcalinization is strong.

Thus, it is crucial to be aware of the composition and properties of water before irrigation.

Alcalinization of soils on biological basis

It is plants which play a crucial role in alcalinization of soils on biological basis. However, it is special plants, not each of them, which perform this function. Plants influence alcalinization process in two ways. First, vital activity of these plants proper, on the one hand, and subsequent process of their rotting and related effect on alcalinization, on the other.

Widely spread on steppe, desert and semidesert areas are wormwood, wild cereals. They grow under conditions which allow them to ensure salinized environment. As compared with other plants, their composition is characterized by increased quantities of ash content and largely Cl^- , SO_4^{2-} , S^{2-} , P^{3-} , K^+ and Na^+ -ions, especially Na^+ -cation. This is explained as being due to the fact that these plants grow under dry climatic conditions with their roots deep in the soil to extract moisture. Owing to the fact that evaporation is very intensive on desert and semidesert areas, surface layers of the soil become parched and plants are deprived of moisture. For this reason, the above-mentioned plants take roots deep in the soil even reaching bedrock (the latter being moist, in most cases).

Owing to the fact that bedrocks of the zone are mainly composed of ancient sea sediments, they (bedrocks) and related layers of the soil are strongly salinized. For this reason, the soil turns into salinized solution. Using the moisture, plants absorb, together with water, some quantity of salts. These salts are stored on leaves and trunks of the plant as a result of evaporation, sometimes in the form of crystals. Then wind blows them off or rainfall washes the out, and finally these crystals fall down and penetrate into deeper layers of the soil. These salts are mostly composed of Na^+ -cation, penetrate into the absorbing complex and thus result in alcalinization of the soil.

Contributing to the alcalinization of the soil are xerophytes, especially wormwood, whose rotting leads to the formation of salts. Note that these plants contain ash components, and especially Na^+ -cations, in great quantities. When rotted, there emerge NaHCO_3 and Na_2CO_3 , with Na^+ -cation substituting Ca^2+ -cation (if Na^+ -cation is prevailing) in the absorbing complex according to the formula $\text{T} \cdot \text{Ca} + \text{Na}_2\text{CO}_3 \rightarrow \text{T} \cdot 2\text{Na} + \text{CaCO}_3$ which alcalinization occurs

biochemically. Similarly, rotting of organic substances with the help of anaerobic bacteria and Na-sulphate results in the following changes in the soil and formation of soda.



Thus, the alcalinization of soils occurs as follows. Owing to the increase of Na salts in the soil solutions, there is an exchange reaction between Ca- and Na-cations in the absorbing complex. The saturation of the soil with Na-cation results in the loss of soil's structure stability. In this case the structure is exposed to the split and loses its initial form. The presence of Na-bicarbonate and, particularly, its salts in the soil causes the alkalinity reaction and decomposition of organic substances and, hence, formation of holloid solution. As a consequence, it results in the destruction of microaggregate particles. In the course of rainfall soil particles turn into slush. In hot time, this mass of soil dries up and is covered with deep cracks.

Thus, regardless of the ways of their formation the alkali soils gain negative properties and become unfit for cultivation and raising of agricultural crops.

CLASSIFICATION OF ALCALI SOILS

Clefts which emerge as a result of alcalinization form pillarlike structures in the soil. This is to say that the soil acquires some new negative properties. Depending on alcalinization degree, pillarlike layers are deposited at different depths. As has been shown above, the depth of pillarlike layer differently affects the development of agricultural crops. For this reason, it is crucial to correctly measure at what depths pillarlike structures start.

Depending on depths of pillarlike layers' location, alkali soils may be divided into three types:

1. **Crusted alkali soils.** Pillarlike layer starts at the depth of 2-7 cm from surface.
2. **Middle pillarlike alkali soils.** Pillarlike layer is deposited at the depth of 10-15 cm from surface.
3. **Deep pillarlike alkali soils.** Thickness of surface layer is 20-25 cm; pillarlike structure is deposited below this layer.

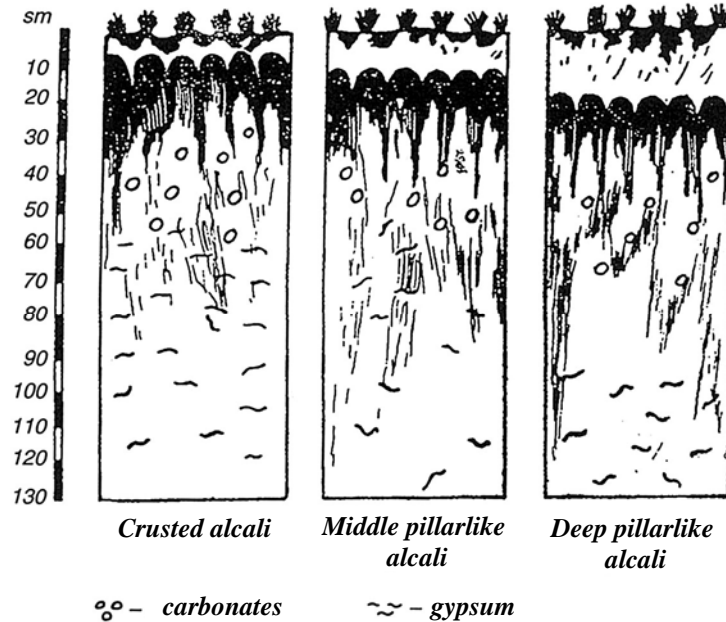


Fig. 10. Types of alkali soils

Note that fertility of crusted alkali soils is very low; that of average pillarlike alkali soils is relatively high; that of deep pillarlike alkali soils is relatively high; that of deep pillarlike alkali soils is rather high.

Depending upon natural conditions, quantity of Na absorbed in the alkali soils is different. To identify alkalinity

properties of the soil, it is unimportant to substitute all Na-cation available in the absorbing complex of the soil.

Experiments showed that the alkalinity of the soil becomes apparent in cases where the quantity of Na absorbed comprises 5%-10% of the total quantity of cations absorbed (Ca, Mg, Na, sometimes K). A typical quantity of Na absorbed in the soil is 20% of the total cations absorbed.

Depending upon the alkalinity degree, these soils may be grouped as follows (when adjusted for the quantity of exchange Na, according to I.K.Antipov-Karatayev):

Quality of Na on non-alkali soils –	less than 5%.
Quality of Na on poorly alkali soils –	5%-10%.
Quality of Na on alkali soils –	10%-20%.
Quality of Na on alkali soils above	20%.

There more the quantity of Na absorbed, the more apparent are negative properties of the soil. Negative properties become apparent on typical alkali soils.

ON LAND-RECLAMATION OF ALCALI SOILS IN AZERBAIJAN

THE NATURE OF ALCALI SOILS' LAND- RECLAMATION

It would be appropriate to note that researchers paid not enough attention to the study of the genesis of alkali soils in Azerbaijan. The same is true of the analysis of land-reclamation problems. There is just few monographs and research works on the subject, which deal with some aspects of land-reclamation. Suffice it to mention works by J.M.Huseynov (1941), Y.P.Logunova (1952, 1955), A.A.Shoshin (1954), M.R.Abduyev (1955-1959).

As has been noted above, insufficient fertility of alkali soils is accounted for by domination of soda and prevalence of Na-cation quantity in the absorbing complex of the soil. They provoke alkalinity reaction in the soil and contribute to washing organic substances from upper to lower layers. In doing so, there is shaped pillarlike structure with negative properties from agronomic point of view. As a result, physical-chemical properties of the soil deteriorate, its water-permeability reduces, a hard crust is formed on the surface after irrigation and the fertility of the soil decreases. For this reason, to improve alkali soils, it is essential to neutralize soda, substitute it for Ca-cation in the absorbing complex, create agronomically favorable structure in place of pillarlike structure and ameliorate physical-chemical properties of the soil and raise its water permeability. Thus, it is essential to create favorable conditions for microbiological processes in the soil and thus, raise its fertility.

With that end in view, it would be appropriate to take necessary measures to improve alkali soils. At present, some of them are being introduced in the production and positive results have been obtained.

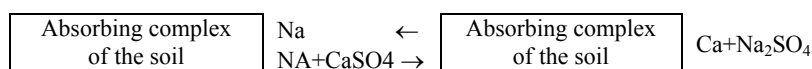
Specific methods are applied to improve alkali soils. An emphasis is laid on chemical reclamation, i.e. gypsuming, and this yielded positive results.

Land-reclamation of alkali soils in deep ploughing

Above-mentioned methods aim to substitute Na-cations for Ca-cations in the absorbing complex. For this to happen, it is essential to artificially enrich the soil with Ca-salts (CaCO_3 , CaSO_4). There are cases where Ca-compounds are piled up on upper layers of alcalinized soils or at their small depths. Therefore it is unnecessary to add Ca-compound in the soil. The point is that Ca-compound in the soil is inevitably drawn in land-reclamation procedures. It should

be noted that Ca-compound is usually stored in the lower layers of the soil, at a depth of approx. 30 cm. A deep ploughing is carried out to draw Ca-compound in land-reclamation procedures. In this case, Ca-compound in the lower layer turns into the upper layer. Affected by rainfall or irrigation, the said compound is gradually dissolved to form a Ca-solution in the soil. This solution gradually penetrates in the lower layers of the soil, enters into exchange with Na, displaces it from the absorbing complex and thus transforms it into the soil solution. As a rule, among new derivatives of Ca-compound in the lower layers of alkali soils there are CaSO_4 and sometimes CaCO_3 . Frequently found in the alkali soil solutions are Na_2CO_3 , NaCl and Na_2SO_4 . Therefore, Na-cation dominates in the absorbing complex of the soil.

The above-mentioned factors account for exchange reaction and changes in the absorbing complex in the course of interaction between Na- and Ca-compounds during deep ploughing:



Accumulation of Ca-carbonate or Ca-sulphate compounds in the lower layers of salt or alcalinized soils is widely spread in the south-east of Azerbaijan, Shirvan plain. When carrying deep ploughing, it is admissible to use soil gypsum for land-reclamation. An eloquent testimony to the fact are experiments of Y.I.Logunova (1955).

Biologically based improvement of alkali soils

As far back in the 1900s, W.R.Williams touched upon the role of organic substances that “we can reanimate bedrocks and turn them into the soil through enriching them with organic substances”.

W.R.Williams' thesis equally applies to the improvement of alkali soils as well. Some researchers of our country have been involved in improving alkali soils on the basis of this method. Worthy of notice are works by Y.P.Logunova (1955).

As a result of Logunova's explorations in the south-eastern part of Shirvan plain it was found that using their roots plants adopt during the vegetation period some 1,0-1,4 tons of ash substances with Ca-, Mg- and K-cations prevailing in this process. The said cations are piled up in the south-eastern part of Shirvan plain inside different plants of the area. The researcher points out that Na- and Ca-ions dominate in wormwood, Ca, K and SiO₂ in ephemerals.

After the termination of vegetation period the plants are exposed to rotting. In doing so, the plants carry soluble compounds of the said elements over to the lower layers via the surface waters.

Logunova noted that the above-mentioned elements are found in greater quantities in the root system of wormwood and ephemerals as compared with supra-soil parts.

Basically contributing to the biological circulation of the elements in the soil is Ca-cation. This is explained as being due to the fact that Ca-cation prevails in ephemerals. On the other hand, as a result of their short-lived and vulnerable vegetation period ephemerals completely rot and thus, contribute to increased circulation of Ca in the soil.

Having piled up on the surface and been gradually solved down, Ca-cation enters into exchange reaction with Na-cation and thus, helps remove alkalinity from the soil. Proceeding from laboratory and field tests, Y.P.Logunova established that the cultivation of lucerne (cultural crop) and ephemerals makes it possible to remove alkalinity and visibly change physical-chemical properties of the soil. These changes are accounted for by a) the reduction of Na-

cation quantity in the absorbing complex under the effect of Ca-cation; b) the reduction of the soil fragmentation by 1,5-2 times at the expense of rise in aggregate fraction (1-7 mm); c) the increase of aggregates' water resistance and rise in water permeability.

Proceeding from the results of field work on the south-eastern part of Shirvan plain, Y.P.Logunova concludes that the cultivation of lucerne and other cultural crops on alcali soils helps create stock of forage for cattle and simultaneously improve the root system of the said crops and, hence, reclaim properties of alcali soils.

Gypsuming and improvement of alcali soils

The most effective way of improving alcali soils is to carry out their gypsuming. This method was suggested by acad.K.K.Gedroyts and later tested and approved in field conditions.

According to the decision of the Cabinet of Ministers of the USSR of 19 September 1949, the Soviet Ministry of Agriculture and Committee for Sovkhozes were instructed to start gypsuming alcali soils since 1950. Under the instruction, it was required to gypsum alcali soils spread in different soil and climatic zones. The instruction also stressed the necessity of creating favorable conditions for land-reclamation (preparation of ground gypsum, granting long-term credits to kolkhozes, sales of gypsum to kolkhoz at cheaper prices, etc.) and thus, contributed to the gypsuming intensification.

The Soviet researchers proved that the gypsuming of alcali soils would make it possible to raise productivity of agricultural crops, including harvest up to 6-10 centers per ha; cotton – 2-3 centners per ha; turnips – 50-100 centners per ha; grass – 5-15 centners per ha.

When gypsuming the alkali soil, it is essential to raise gypsuming capability. The use of softened gypsum proved to be more effective for land-reclamation purposes. Therefore, before gypsuming, it would be appropriate to soften gypsum, then sieve it (diameter 1 mm) and finally re-sieve 70%-80% of pulverized mass through a 0,25 mm diameter sieve.

As a rule, there is some water in the gypsum composition. Thus, 79,7% of gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) is composed of CaSO_4 and chemically bound water. When softened, the gypsum's hygroscopicity increases to let additional water in. the quantity of water absorbed in the gypsum cannot exceed 6%-8%. When exceeded, particles of gypsum stick together and form clots. In this case, the influence of gypsum on the soil considerably reduces. That's why it is necessary to store gypsum in closed places to protect against moisture.

Note that the gypsuming of alkali soils may be carried out both on unwatered and irrigable soils. In both cases, it is crucial to raise solubility of gypsum, correctly fix the date and place of soils to be gypsumed, especially unwatered soils. Gypsum's effect on the soil is maximum, if it is well and truly intermixed with the alcalinized layer of the soil with moisture being at its maximum. Owing to the high moisture on yerik-ploughed site and through intermixing gypsum with alcalinized part of the soil, it would useful to carry out gypsuming operations on unwatered soil ploughed on yerik-based method. It would also be advisable to apply a gypsum sowing rate during autumn ploughing on unwatered soil.

As for droughty zones of Azerbaijan, it is advisable to apply half of gypsum in autumn ploughing, half in sowing season gypsum in autumn ploughing, half in sowing season (cotton or perennial herbs).

To attain the goal, it is necessary to apply a greater quantity gypsum to the alcalinized layer of the soil, its

compact portion. Gypsuming occurs at great depths, since compacted alcalinized layer is deposited at a certain distance from the surface.

As has been noted above, depending on the type of alcali soil the alcalinized layer may be deposited at different depths. For this reason, the ploughing sometimes does not embrace a compacted portion of the alcalinized layer. Thus, depending on the type of alcali soil the gypsum application methods are different.

Owing to the fact that the alcalinized layer of *crusted alcali soils* is located at shallow depths, in the course of ploughing the whole of alcalinized layer is turned out on the surface. That's why, when gypsuming the whole gypsum is spilled over the soil and then the ploughing layer is thoroughly intermixed (Fig.11).

In the course of ploughing of *middle pillarlike alcali soils* a 5-6 cm layer of the soil is turned out on the surface. In this case, half or $\frac{1}{4}$ of gypsum is spilled over the site before the start of ploughing. The rest of gypsum is spilled over the site and mixed with the layer being ploughed.

In the course of *ploughing of deep pillarlike alcali soils*, the ploughing layer is deposited deep in the soil, so this layer is not processed. Therefore, a gypsum application rate is spilled over the soil before ploughing, and it is ploughed. In this case, when turned out the gypsum gets into the ploughing layer.

The distribution of gypsum over the ploughing site must be even everywhere.

During gypsuming it is advisable to apply super phosphate on the site. Nitric fertilizer (ammonium-sulphate) should be applied before spilling.

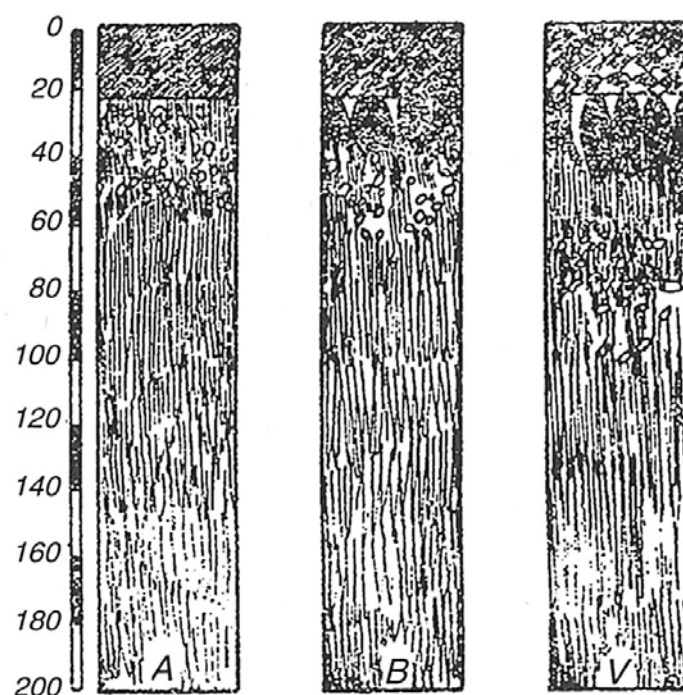


Fig.11. Disorder of pillarlike structure of alkali soils in the course of ploughing

A – crusted alkali soil; B – middle pillarlike alkali soil;
C – deep pillarlike alkali soil.

After gypsuing the site in autumn, it is essential to irrigate an area of 1000 m^3 , which yields good results. It is necessary to repeat this procedure every autumn. But in this case it is crucial to take into account hydrogeological conditions of the area. If ground waters are located at shallow part of the gypsumed area it is possible to raise water irrigation rate to thus increase solubility rate. Otherwise, ground waters may raise water level and thus increasingly salinize the soil.

Calculation of gypsum rate during the improvement of alkali soils through gypsuming

When gypsuming the gypsum rate is calculated to comply with Na absorbed in the soil. To calculate gypsum rate to be applied in the soil, the following information is essential:

1. The ekv. quantity of Na absorbed per 100 g soil.
2. The ekv. quantity of cation absorbed per 100 g soil.
3. Specific weight of the alcalinized layer.
4. Thickness of humus layer.
5. Depth of sand layer.

This information available, the gypsum rate in the alkali soil is calculated as follows.

Suppose that we dispose of the following information about the gypsum rate to be applied in the soil:

1. The ekv. quantity of Na absorbed per 100 g soil – 12 m ekv.
2. The ekv. quantity of cation absorbed per 100 g soil – 60 m. - ekv.
3. Specific weight of the alcalinized layer of the soil – 1.5.
4. Thickness of humus layer – 17 cm.
5. Depth of sand layer – 30 cm.

As has been stated above, when the quantity of Na-cation absorbed in the soil makes up 5% of bases, it has negative effect on physical properties of the soil and the development of plants. Na-absorbed in the soil is called “non-active” Na. For this reason, when gypsuming alkali soils, it is not provided to remove all Na-cations absorbed. Thus, 5% of Na absorbed in the soil is removed, the rest is calculated to comply with gypsum rate according to “active Na”. In other words, the gypsum rate is calculated in accordance with above established standards: if we take total of bases absorbed as 60 m. – ekv. 100%, in this case 5% of Na absorbed will make up 3 m. - ekv.:

$$\frac{60 \cdot 5}{100} = 3 \text{ m.-ekv.}$$

If one subtracts “non-active” Na from total quantity of Na absorbed (12 m.-ekv. – 3 m.-ekv. = 9 m.-ekv.), it is possible to calculate quantity of “active” Na in the soil. When calculating the gypsum rate in the soil, it is essential to proceed from 9 m.-ekv of Na, not 12 m.-ekv.

Let's calculate now the specific weight of alcalinized layer of the soil to be gypsumed. Specific weight of 1 cm³ alcalinized layer is 1.5 g. At a depth of 1 cm the specific weight of 1 m³ is 1.5x10,000=15 kg; at a depth of 10 cm is 15x10=150 kg.

Now it is necessary to calculate the quantity of Na absorbed on 1 m² of soil if the quantity of Na absorbed in 100 g of soil is 9 m.-ekv., hence, the quantity of Na absorbed in 1 kg of soil is 9.1000/100=90 m.-ekv.

At a depth of 1 cm the specific weight of 1 m² alcalinized layer is 15 kg. At a depth of 10 cm the figure is 1350x10=13500 m.-ekv. Thus, in order to remove the quantity of Na (13,500 m.-ekv.) absorbed in the alcali soil, it is essential to learn the quantity of gypsum. As is known, there is 11628 m.-ekv. in 1 kg of gypsum; 11628000 m.-ekv. of Ca-cation in 1 t of gypsum. Hence, there is 1350 m.-ekv. of Na-cation absorbed in the soil at 1 cm depth of 1 m³ of the alcali soil layer, so to replace it by Ca-cation, 1350 m.-ekv.: 11629 m.-ekv. = 0.117 kg, or 17 g of gypsum. The quantity of gypsum at a depth of 10 cm on the area of 1 m² is 117 g x 10 = 1170 g.

In spite of the fact that the gypsum has been applied for the alcalinized layer only, during the ploughing the whole of the humus layer and partly the alcalinized layer are ploughed. Despite this, the gypsum rate is calculated to comply with the thickness of the alcalinized layer only. The

thickness of the alcalinized layer conformably to the current conditions is $30\text{ cm} - 17\text{ cm} = 13\text{ cm}$. Thus, if 117 g of gypsum is required for gypsuming of 1 m^2 of the soil with thickness of 1 cm, hence, $117 \times 13 = 1521\text{ g}$ of gypsum are required for the soil layer with thickness of 13 cm.

To calculate 1 ha of the soil, it is essential: $1521\text{ g} \times 10000 = 15.21\text{ tons}$.

Change of physical-chemical properties of soils as a result of gypsuming

The gypsuming of soil occurs when Na-cation is removed from the absorbing complex and substituted for Ca-cation. First of all, physical-chemical and agrochemical properties of the soil are improved as a result of process. The improvement of these properties means the improvement of the structure of this soil. An eloquent testimony to the fact is the results of experiments carried out by J.M.Huseynov in Khudat region, Chkalov sovkhos.

The researcher added 5-10 tons of gypsum per hectare on patches with total area of 100 m^2 . In doing so, he found out that the gypsum considerably improved micro-aggregate properties of the soil. As is seen from Table 8, the quantity of particles ($<0.001\text{ mm}$) on the area of 0-10 cm is much lower than on control site.

The quantity of particles with size 0.005-0.001 mm on the gypsumed area has risen at the expense of the reduced particles with size $<0.001\text{ mm}$.

The quantity of particles with size 0.005-0.001 on the layer of 10-20 cm thickness is much lower. Owing to the reduction of these particles, the quantity of particles with size 0.01-0.005 has reason by 1.5 times.

As is seen from the J.M.Huseynov's experience, the positive influence of micro-aggregate properties of the soil

manifests itself on the area ploughed, but not sown. This influence occurs at a depth of 40 cm of the soil. The positive influence of gypsum is obvious at a depth of 10 cm. Thus, if the quantity of <0,001 mm particles is 16.38% at a depth of 10 cm, the same particles make up 8.61% on the 5 t gypsumed site; and 4.96% on the 10 t gypsumed site.

The same correlation is observed at depths of 20, 30 and 40 cm (J.M.Huseynov, 1941).

J.M.Huseynov carried out experiments on hard clay soils of Samur-Devechi canal and concluded that in applying 5 and 10 tons of gypsum per ha on the alcalinized soils it would be possible to essentially improve their microaggregate properties.

It should be noted that the application of gypsum on the alcalinized soils helps improve physical properties of the soil and at the same time raise its water permeability and conservation.

In applying 10 tons of gypsum per ha of gray alcalinized soils of Ujar region made it possible to establish that the water permeability of the soil in the ploughed layer rose by more than 2 times, and in the sub-ploughed layer by 3 times.

Also, owing to the gypsuming it became possible to raise water permeability of the soil in the ploughed layer by 2 times, and by 2.5 times in the subploughed layer on the gray alcalinized soils of Kurdamir region. At the same time, water permeability of meadow-gray alcalinized soils of the same region was raised by 2 times; and in the sub-ploughed layer by 18 times.

Application of 10 ton of gypsum per ha on the meadow-chesnut alcalinized soils of Aghsu region made it possible to raise water permeability in ploughed and subploughed layers by 2 times.

Meanwhile, water permeability on gray alcalinized soils of steppe regions of the same region rose by 5 times; and in

the sub-ploughed layer by 2 times thanks to the application of gypsum.

Table 8

Influence of gypsum on microaggregate composition of the soil under vegetation (J.M.Huseynov, 1941)

Diagram of experience	Depth, cm	Quantity of fractions, %					
		1-0,25 mm	0,25-0,005 mm	0,05-0,01 mm	0,01-0,005 mm	0,005-0,001 mm	<0,001 mm
Control	0-10	0,72	12,95	26,25	13,86	29,21	16,67
	10-20	0,68	10,84	25,75	12,17	36,05	14,51
	0-10	0,91	12,01	27,25	11,61	36,24	11,98
	10-20	0,63	8,64	25,85	19,47	30,15	15,26

An eloquent testimony to the above-mentioned is Fig.12.

Positive effect of gypsum application is confirmed by field experiments. Application of 5 and 10 tons of gypsum per ha on alcalinized soils of Siyazan and Sumgait kolkhozes helped establish that gypsum raises water permeability of the soil from 5 times (5 tons per ha) to 8 times (10 tons per ha). If 15 tons of gypsum is applied on the test alcalinized soil (Ali Baiyramly and Mingchevir tests), water in the volume of 4,000 m³ per ha is absorbed within 10-12 hours, while the same volume of water is absorbed on the non-gypsumed area within 8-10 days.

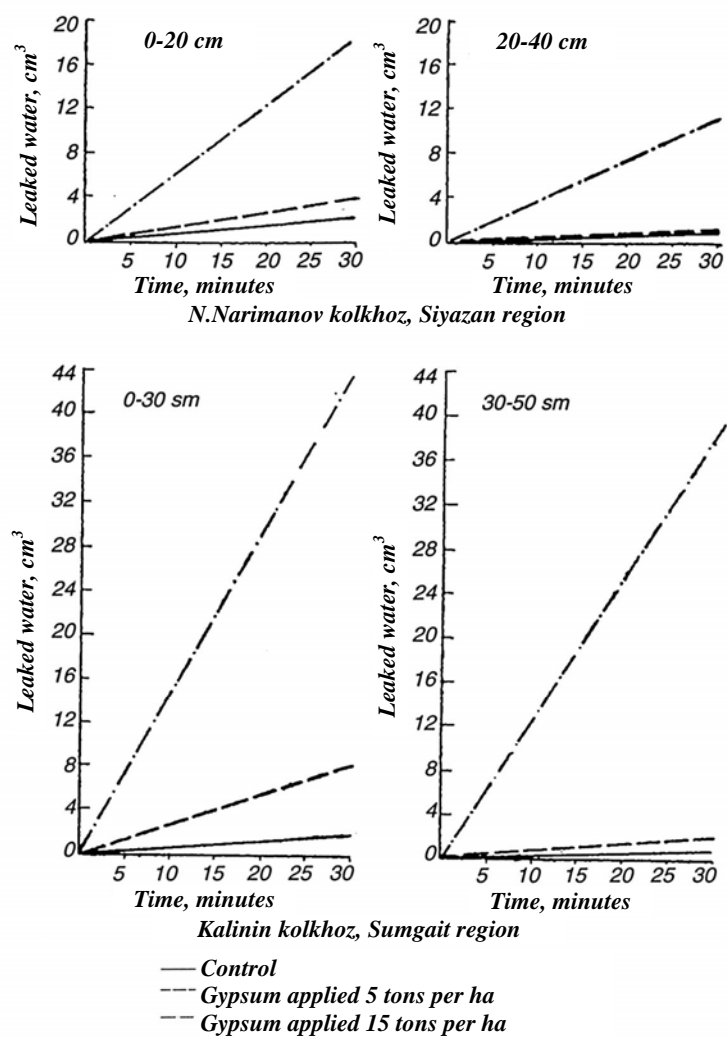


Fig.12. Influence of gypsum on water permeability of the soil

As has been noted above, the moisture is kept for long period on the test gypsumed alcalinized area as compared with the non-gypsumed area. Note that the water permeability visibly rises if, together with the gypsum, a manure is applied. An eloquent testimony to the fact is the results of experiments we have carried out. In particular, if 15 tons of gypsum per ha is applied on the test area, the moisture is above 2.19% - 7.50%. If 10 tons of gypsum together with 40 tons of manure per ha is applied on the test area, the moisture is 5-8%; if gypsumed only, the moisture is above 0.69%-2.76%.

It should be recalled that the quantity of easily soluble salts in the lower layers of alcali soils is rather great. If gypsumed, the alcalinized soils provide for increased water permeability and ability for storing moisture. This, in turn, has a positive effect on salts' washing out of the lower strata of the soil.

As for washing of salts in the course of alcalinized soil's improvement, their dynamics calls for more detailed information. Of interest are the results of experiments carried out on alcalinized soils of a sovkhos in Ali Bayramly region. Tests were carried on in three ways. Non-gypsumed check area, experimental sites with 15 tons of gypsum per ha and with 10 tons of gypsum and 40 tons of manure per ha. All three experimental sites were watered (volume – 4,000 m³) thrice (4,000 m³ + 4,000 m³ + 4,000 m³). Area of experimental sites was 15 m² each.

It was established that the non-gypsumed check area was watered 4,000 m³, and due to natural cracks on the surface of the soil the water penetrated into a certain depth and the quantity of salts in the upper layer (depth ½ metre) dropped three times. Note that Cl-ion fell ten times. The situation was different in the second and third cases. Owing to the fact that the soil was characterized both by salinization and

alcalinization processes, small particles of the soil swelled after the first watering and filled voids. For this reason, the second and third waterings failed to penetrate in the lower strata of the soil. Under current circumstances, there occurred a salt balancing between solution of strongly salinized layer and that of lower layer.

As a result of evaporation, the soil solution becomes denser, dries and the salts are piled up in the upper layer. Therefore during the second and third waterings in the volume of 4,000 m³ per ha result in raising salts in the upper layer. This is a distinctive feature of alcali soils.

When 15 tons of gypsum per ha are applied in the soil, the results are opposite. In this case, water in the volume of 4,000 m³ penetrated into the depth of ½ m and reduced the quantity of Cl salts by 30 times and the total quantity of salts by 2 times. Following the second watering in the volume of 4,000 m³, there was an increased quantity of salts in the soil profile and their washing into deeper strata. This time, half of total quantity of salts and a considerable amount of Cl-ion were washed out in the soil profile and their washing into deeper strata. This time, half of total quantity of salts and a considerable amount of Cl-ion were washed out in the 125 cm profile.

It would be appropriate to note that high alkalinity, typical for alcali soils, is substantially neutralized in the gypsuming process. Experiments demonstrate that following the first and second watering on the test plot the total alkalinity dropped more than twice.

Following the third watering in the volume of 4,000 m³, despite a considerable drop in the total quantity of salts in the soil profile, the quantity of HCO₃ rose, and CO₃-ion, though very insignificantly, appeared. This is accounted for by the penetration of dissolved of gypsum after the second

watering in the lower layer and its depletion in the upper layer.

It should be noted that the third watering is no longer required to reaffirm our concept. Thus, following the second watering the quantity of salts in the 75 cm layer made up less than 0.4% on the average. As viewed by many researchers (V.R.Volobuev, 1947; A.A.Shoshin, 1955), this quantity is not harmful to cotton and cereals. To our thinking, it would be quite enough to carry on two waterings with 15 tons of gypsum per ha in the course of saline alkali soil reclamation.

According to the third version of our experiment, 10 tons of gypsum and 40 tons of manure per ha were applied. Like the first and second waterings (4,000 m³), there was an essential reduction in the total quantity of salts, Cl and alkalinity in the soil profile. At the same time, there was an apparent washing of salts under this version. Still, following the third watering there was rise in the total alkalinity of the soil and emergence of CO₃-ion. It would also be enough to carry on two waterings (4,000 m³) to improve saline alkali soils.

The above-stated facts are indicative that it is possible to improve alkali soils and raise productivity of related agricultural crops.

CONTENTS

Introduction	3
Geographical distribution of alcali soils and reasons of their formation	5
Definition of alcali soils	5
Saline soils.....	6
Alcali soils.....	7
Influence of absorbed cations on the development of plants	9
Geographical distribution of alcali soils.....	11
How alcali soils are formed.....	12
Eluvial alcalinization.....	12
Alcali soils formed on deluvial basis	17
Alcalinization that precedes salinization	27
Alcalinization of soils under the effect of salinization process	29
Alcalinization of soils due to washing out of salinized soils	32
Alcalinization of soils on biological basis.....	41
Classification of alcali soils	43
On land-reclamation of alcali soils in Azerbaijan	45
The nature of alcali soils' land-reclamation	45
Land-reclamation of alcali soils in deep ploughing	46
Biologically based improvement of alcali soils	47
Gypsuming and improvement of alcali soils	49
Calculation of gypsum rate during the improvement of alcali soils through gypsuming	53
Change of physical-chemical properties of soils as a result of gypsuming.....	55

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AND THEIR IMPROVEMENT**

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