

SALINITY CONTROL ON IRRIGATED LANDS

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The areas under irrigation constituting 235 mill. ha or 16% of all agricultural lands, are known to yield over 50% of the world's entire agricultural produce. Thus, in the Soviet Union, where the average yield of raw cotton has exceeded 30 q/ha, that of rice - 40 q/ha and of wheat - 24 q/ha, etc.

However, despite favourable climatic conditions, many countries of highly developed irrigation feature by far lower specific productivity of irrigated lands. Thus, in 1973-1974, the rice yield in India made up 14.5 q/ha, cotton yield - 9q/ha, wheat yield 13.8 q/ha, in Pakistan respectively - 22.6; 10.4; 11.9 q/ha; in Iran - 31.6; 9; 17.2 q/ha. Among numerous factors responsible for the existing level of agricultural crop yields are found unskilled farming, lack of fertilizers, inadequate mechanization of farming practices.

The principal one in a number of countries is salinization of lands under irrigation. So, the results of research

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** Hereinafter q - quintal = 100 kg.

done by the Secretariat of Water Resources of Mexico in Irrigation District No.41, state of Sonora, have shown that low salinity of land reduces the yield of agricultural crops by about 5%, medium salinity - by 50%, high salinity - by 90%, solonchaks - by 100%. In the opinion of V.A.Kovda, low salinity decreases crop yields by 20%, medium salinity lowers it by 40-60%, apart from complete failure of most crops in solonchak spots of these lands. From the data reported by I.Baumans, V.Houlsbols et al., salinity of irrigated lands in Iraq; estimated at 10 mmho/cm by EC_e , reduces the barley yield by 40%, at 18 mmho/cm - down to 65%.

The results of soil salinization impact on yields as presented by Bernstein are given in Fig.1, and those reported by different Soviet researchers for Central Asia (V.M.Legostayev, Kh.I.Yakubov, I.K.Kiseleva, I.S.Rabochev) are adduced in Fig.2. Both figures show that the nature of salinity influence is identical for the data of all investigators. Taking into account the fact that soil salinization in India, for example, covers 20% of the irrigated area, and about half of it in Pakistan and Iraq, it becomes clear that the yield losses on saline lands inflict great damage to mankind annually. The above-mentioned research done by Mexican reclamationists has shown that the income yielded by soil desalinization averages 1000-1100 Mexican pesos per 1 ha, or 130 dollars per 1 ha. As far as we have found out, radical reclamation of saline lands brings 200 to 500 roubles of annual income per 1 ha. By the data of V.A.Kovda, American experts estimate the damage inflicted by salinization

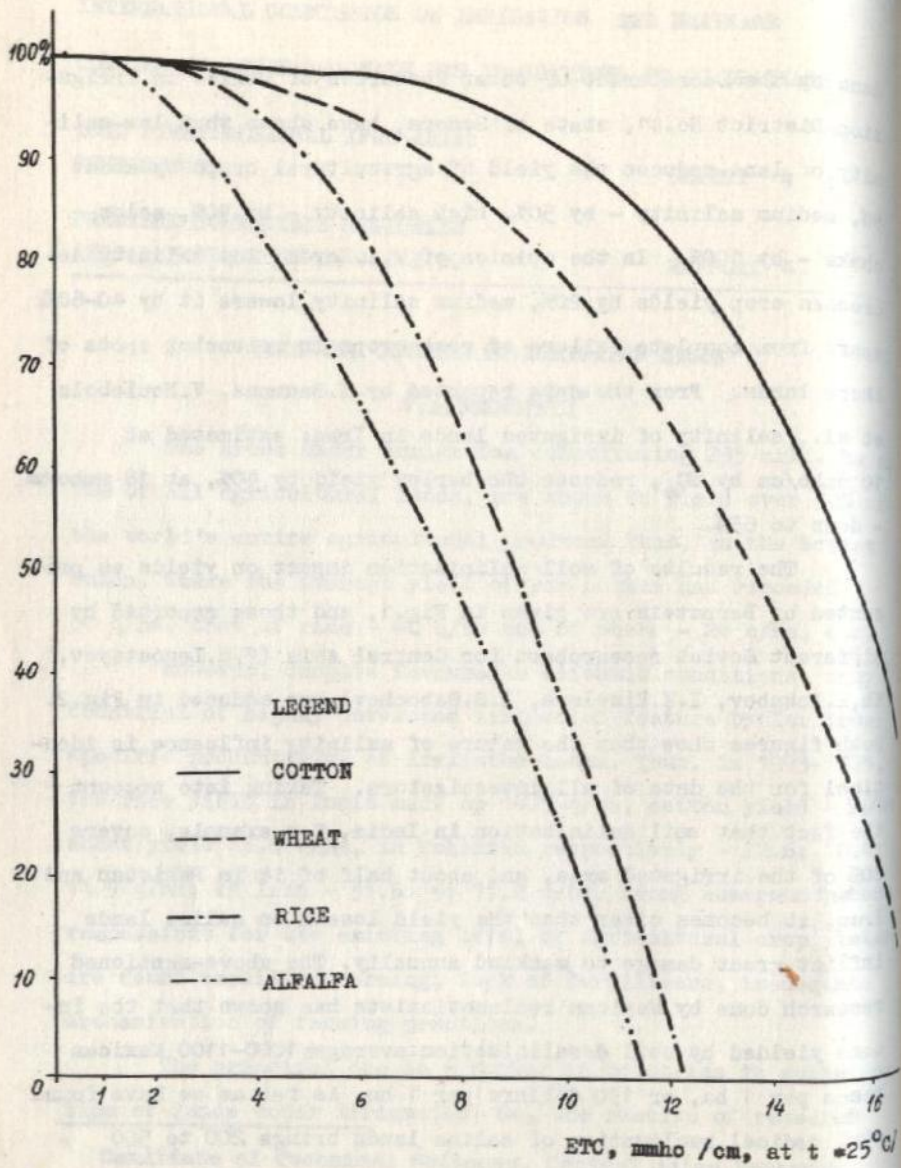


Fig. 1. Reduction of crop yields as adduced by Bernstein.

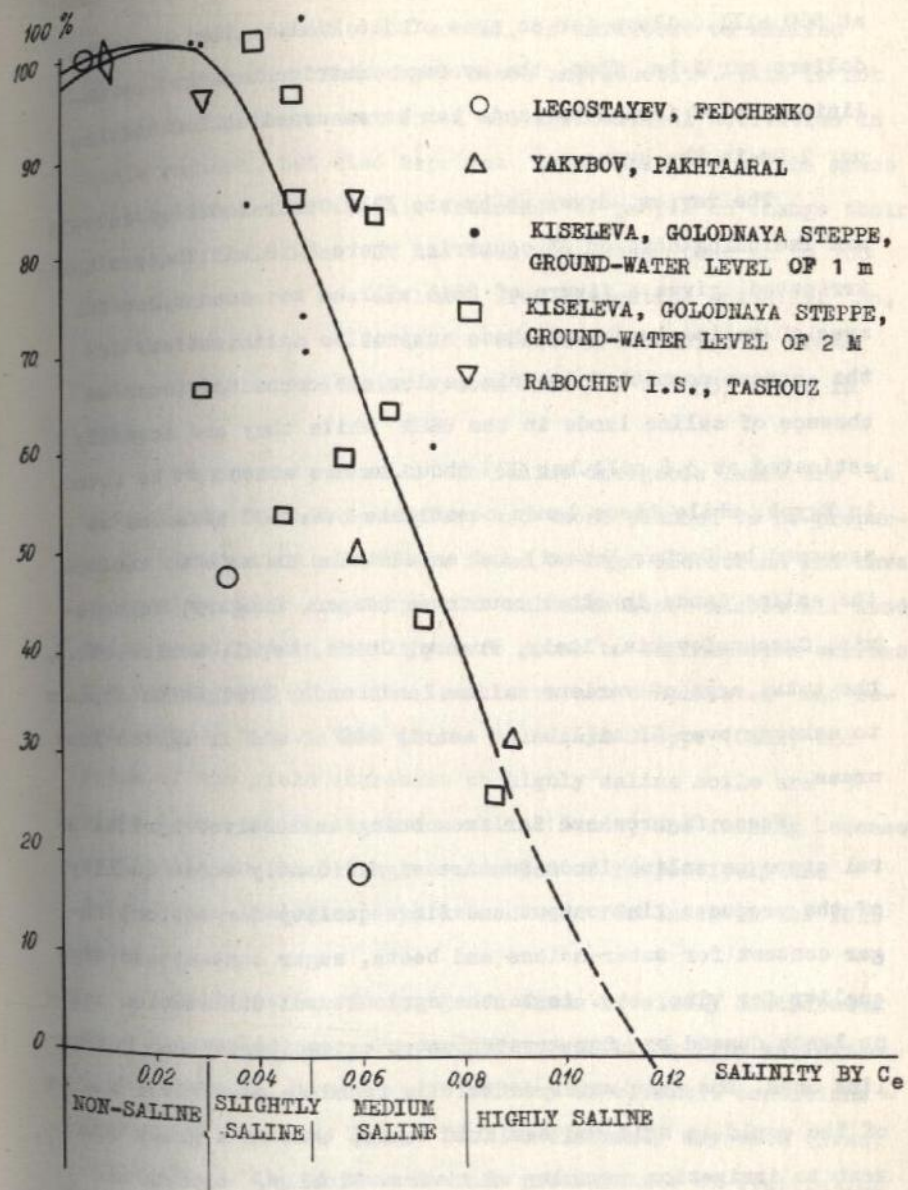


Fig. 2. Raw cotton yield as influenced by salinization degree.

at 350 mill.dollars for an area of 1.6 mill.ha, or about 200 dollars per 1 ha. Thus, the average detriment caused by salinization of irrigated lands can be assessed at 200 dollars per 1 ha in the average.

The review, drawn up by the ICID Central Office in 1973 and including data on 23 countries where 87.8 mill.ha are being irrigated, gives a figure of 28.4 mill.ha to account for the area of saline lands and those subject to salinization. If the errors committed in this review are corrected (such as absence of saline lands in the USSR while they are actually estimated at 3.6 mill.ha; 225 thous.ha are stated to be found in Egypt, while these lands constitute over 600 thous.ha as assessed by Doctor Kenawi) and an addition is made to include the saline lands in other countries (Japan, Hungary, Yugoslavia, Czechoslovakia, Italy, France, China, Nepal, Mexico, etc.), the total area of various saline lands under irrigation appears to make up over 50 mill.ha or nearly 20% of all irrigated land areas.

These figures are far from being exhaustive. Agricultural crops on saline lands feature significantly worse quality of the produce: lint output and fibre quality for cotton, sugar content for water-melons and beets, sugar content and wine quality for vine, etc. As to the agricultural utilization saline lands demand by far greater water expenditures than non-saline ones. Now that water deficit is found in most river basins of the world in arid and semiarid zones, this is a great detriment to irrigation capacity of rivers. Finally, tremendous

damage, both economic and social, is inflicted to mankind when lands get salinized and hence unproductive. This is not limited only to cessation of all agricultural activities in whole regions, but also deprives the population of the means of subsistence and compels thousands of people to change their places of residence. It has been estimated that up to 100 thousand hectares are excluded from irrigation annually. So, in Pakistan, soil salinization caused a reduction of areas under cotton in the Sukkur system from 44% in 1937 to 2% in 1963.

At present, fertile non-saline irrigable lands are in use already in most countries, and those planned to be prepared for irrigation either are found at high elevations and have steep slopes, or are subject to salinization. Almost all lands being developed in Povolzhye are prone to salinization whereas the development of saline land is rather complicated and requires much time. Thus in the Golodnaya Steppe (USSR) the rates of the yield increment on highly saline soils are 3 times less than those on non-saline lands, and farming becomes profitable in the 8-9th year instead of respectively the 2-3rd year. Analogous data are adduced for India in the ICID report.

Salinization of irrigated lands is widely distributed over the world's map. The countries suffering from salinization phenomena, have a great variety of climatic conditions - from moist (Canada, Taiwan Is.) to extremely dry ones (Iran, Iraq, etc.). All of them feature predominance of evaporation

over precipitation either by a total throughout a year or during some seasons. The widest spread of soil salinization occurs in arid and semiarid zones. In such countries as Iran, Turkey, Iraq and Pakistan, saline lands constitute 50% and up of the entire irrigated area, while in India, the USA, the USSR, Syria, ARE, Australia, 20-30% of the lands under irrigation are subject to salinization. Solonchak soils are also noted to be available in the wooded steppes of the East and West Siberia (E.S.Khils, V.V.Yegorov), in the high-mountain plateaus of Mexico, Hungary (I.Sabolch), Yugoslavia (M.Moreli), Rumania (G.Obriyanu), where rainfall is by far greater than the volume of evaporation. The spread of saline lands is strongly dependent on the salinity origin. V.A.Kovda distinguishes the following cycles and types of salt accumulation.

1. Continental ones have their origin in the processes of rock disintegration, salts (carbonates, sulphates, chlorides) isolation, movement, re-distribution and accumulation in intracontinental blind-drainage areas. This type falls into primary and secondary salt accumulation; the former (Little Caucasus, Mongolia) is based on the products of weathering and soil formation building up in water and soil, while the latter (Ferghana, Chile, Iran, etc.) implies re-distribution of those products.

2. Maritime ones form under the influence of sea water and accumulation of its salts mainly sodium chloride, in coastal lowlands (Japan, Austria, the Netherlands, France, etc.).

3. Delta-type ones result from the salts entry with

surface and ground water, and their interaction of the latter in ancient river deltas (the Amudarya, Tigris, Huanghe, Nile, etc.)

4. Artesian ones depend on the evaporation of pressure ground water coming onto the surface or near it (Caspian Depression, Usturt, the Colorado upper reaches, etc.).

5. Anthropomorphic ones appear due to the wrong ways of man's influence upon nature and consequent sharp changes in the natural environment leading to salt accumulation or re-distribution (rise of ground-water level) during irrigation, use of saline water for irrigation).

Most countries assess the suitability of water for irrigation by the total salt content, alkalinity and toxicity of separate ions. Among classifications by the total salt content, the most widely used one is the classification worked out by the Salinization Laboratory under the US Department of Agriculture. Similar classifications are applied in Australia and Egypt. Durand (France) has developed a classification including the physical state of soils and salt tolerance of crops. The classification implies that the salinity permissible for salt-tolerant crops is up to 2 g/l for loam, up to 3.2 g/l for loess loam, up to 4 g/l for loamy sand, and up to 8 g/l for sand.

Particular attention is paid by all countries to the hazard of excessive sodium content in water which can cause soil alkalinity. The hazard is estimated by the combination of sodium salts with those of calcium and magnesium. This combination is expressed by sodium adsorption ratio (SAR).

The data available now show that the danger of sodium salinization is insignificant for most countries, except for West Pakistan, south-eastern part of the USA (the Pecos river in New Mexico, the Gila in Arizona and a number of others.

Some countries distinguish specific ion concentration limits: for chlorine and boron. Nilson, Bigger and others think the chlorine content of 4 me/l to be safe, that of 8 to 4 me/l less dangerous, and the content of more than 8 me/l dangerous. In Israel these limits are set a bit higher: 6.0 7.5 and 9.0 me/l respectively.

Boron ions are hazardous for most crops even in low concentrations. It is hard to be leached. The boron danger has been discovered in India (Punjab), the USA, Japan, Turkey.

It should be kept in mind though that the danger of salt accumulation might not become apparent under some conditions and get enhanced under others. Thus in India, mineralized water is efficiently used for irrigation of naturally and artificially drained lands, with salinity up to 5 g/l as in Rajasthan and up to 7-8 g/l as in Haryana, precipitation preponderating over a year.

Adequate drainage conditions constitute the major factor reducing salt accumulation. It is known that long before our era, lands in the Tigris and Euphrates interfluvium in Mesopotamia were subject to intensive salinization due to insufficient drainage and constant entry of salts with irrigation water. American scientists have found out that as far back as the XIV century, the lands in the Salt River valley went

out of agricultural use and were deserted due to the same reason.

Special attention is drawn by the fact of intensive salinization development in Pakistan where accretion of irrigated land areas is unjustified because of insufficient increase of water withdrawal. The area under irrigation in the Lower Chenab Canal zone has grown by 80%, the volume of total water withdrawal from canals remaining the same; this has caused the irrigation requirements to decline from 11400 m³/ha to 6350 m³/ha, which does not suffice to replenish the moisture deficiency. Consequently, a leaching regime has not been provided and land salinization has greatly progressed.

Irrigation of lands under poor drainage conditions with mineralized water is accompanied by the increase in ground-water salinity. Thus, over 20 years (1947-1968), the content of chlorides in the Beni Amir region, Morocco, rose from 0.05 - 0.87 g/l to 0.211 - 6.46 g/l. Similar phenomena are also found in Israel.

So, salinization development can be stimulated both by one factor out of those mentioned above, and, in most cases, by a combination of them. Therefore, salinization control and prevention measures are to be directed towards eliminating or suppressing the impact of these factors on the soil of irrigated areas.

Creation of reliable drainage is a guarantee of successful farming on saline lands. It permits providing the outflow of ground and infiltration water, and ensuring the required intensity of ground-water level lowering. Use of drainage com-

bined with supply of irrigation and leaching water enables reclamationists to regulate the water-salt and water-air regimes of soils.

Over 3 thousand kilometres of subsurface drainage are built annually on the irrigated lands of the USSR: in the Golodnaya, Karshi and Surkhan-Sherabad steppes, in Azerbaijan, Turkmenia, the Ukraine. As compared to open drainage, a subsurface system ensures a higher land use factor, marked improvement of operation reliability, reduction of operation costs and better durability of structures.

Tile, asbestos-cement, polyethylene, PVC and other pipes are used for subsurface drainage. The diameters of initial drains adopted in most countries do not go below 75-100mm. Filter material is an important drainage element meant for preventing tube siltation and piping phenomena, for provision of adequate intake capacity, the latter being particularly important for soils low water yield and hydraulic conductivity. When no filter is provided or when its size is inadequately small, soil overhang above drains can occur with small discharges. Filter material can be gravel and sand, either natural or especially graded, various synthetic fabrics and fibreglass.

It should be noted that the viewpoint of Soviet specialists is not shared by some American researchers who think it is possible to use drainage without filters, making it denser instead (Meierhofer).

During the last years, the Soviet Union has started

experimental use of drainage tube-filters which combine conveying and filtering functions owing to the porosity of their walls. When applied, they permit reducing the volume of filtering material and with hydraulic conductivity of 1 m/d, discarding it altogether or substituting it for local soil, be it even barkhan sand.

The depth and relative drain spacing are the most important parameters of horizontal drainage. In the ARE, India and Iraq, shallow but dense drainage is used, the depth being 0.8 to 1.5 m and drain spacing ranging from 20 to 40 m. These parameters applied in the USA (the Imperial and Coachella valleys) made up respectively 1.8 - 2.6 m and 60-130 m some time ago. In the recent years, a shift has been made towards the use of deeper drainage, the depth equalling 3 - 3.5 m.

Previously, drainage depth was adopted in the USSR in compliance with the so-called "critical ground-water level". Now, however, the depth is determined according to the specific reclamation regime to result from the drainage construction. Drainage depths for most arid and semiarid zones of the country are taken to be from 2.8 to 3.5 m.

Wide development of horizontal subsurface drainage was stimulated by mechanization of drainage operations. Three methods of drainage construction are applied in the USSR, namely: the trench, slot and trenchless ones. The trench method is mainly used when providing drainage in dry stable or wet, but not susceptible to collapsing and sliding soils. When ground-water level is high, the other two methods are used. The trenchless method is particularly efficient and

economical when employing drain-layers with special working members devised by Soviet specialists for depths of 2.5-3 m and allowing for the construction rate of 2 km per shift and high reclamation efficiency.

In case the area to be drained has a double-layer structure, i.e., poorly permeable soils are underlain with thick easily permeable soils occurring at a depth of 5 - 10 m, it is good practice to employ "combined" drainage. This type of drainage is a combination of horizontal and vertical, self-flowing drains, called amplifiers. In this case the horizontal portion of the drain can be made both open and sub-surface, water-transporting and water-intaking, while the vertical portion always functions as a water intake in the under layer. Such drains are employed to advantage in the USA and this country - in the Tashauz, Khoresm and Karshi regions.

Vertical drainage can be built as tube wells from which water is mechanically pumped out. As early as the Middle Ages, peculiar vertical drainage was attained by pumping out infiltration sea water in the Netherlands, through the use of wind mills.

However, the intensive employment of vertical drainage has become possible with the progress of power engineering, machine- and pump-building. This type of drainage has found extensive application in California, later on, in India, Pakistan. In the recent 15 years vertical drainage has become popular in this country, particularly, in Central Asia and the Ukraine, then in Kazakhstan, Transcaucasia and so on. The

occurrence of the aquifer up to 70-100 m thick and its hydraulic connection with the upper layers provide the best conditions for applying this method of land drainage.

Compared to horizontal drainage, this method has a series of advantages: initial expenses are low; it permits to sharply change the depth of drainage, to create variable pressure and variable space depending on the required cycle of reclamation jobs; it does not require land acquisition either during construction or operation, permits to re-use the water pumped for irrigation. However, compared to horizontal drainage, operation costs are higher, its operation is more complicated and requires more serious inspection; the service life is shorter. The analysis of the overall costs proves that the employment of vertical drainage is reasonable if one borehole is capable of serving 100 irrigated hectares and more.

The creation of reliable and economically attractive drainage which ensures certain conditions cannot eliminate the problem of salinity control. Many cases are known when drained lands continue to get intensively saline if no agricultural operations are carried out. Desalinization requires that drainage be combined with leachings and the irrigation leaching regime, i.e., the combination of drainage and water delivery is to ensure the required reclamation regime. Such combination is responsible for the interaction of irrigation and ground water, thus affecting the value of total water consumption.

The experience gained in irrigating saline lands in

the USSR, particularly, in Central Asia, proves that soil desalinization can be attained under any ground water table occurrence though through the application of different rates of irrigation water. Thus, under shallow drainage provided at the ground water table occurrence approximating 1.5 m in the Khorasm, Tashauz and other regions, steady reduction of the seasonal salt build-up, occurring here, is attained but net irrigation requirements vary from 15 to 17 thous m^3/ha .

Under similar conditions, when drainage is as deep as 2.8 m and the ground water table occurs at a depth of 2.2 - 2.5 m, the total net water consumption on the experimental plots has been reduced to 9-10 thous m^3/ha .

Baumans Houlbols and others conducting experiments in the Dajalah region, Iran, with the use of drainage 1.2 m deep and drains spaced at 25 m, have received the desalinization regime, the volume of water used for irrigation made up 16-17 thous m^3/ha .

El Gabali, ARE, carried out experiments on the "Abis" and "Itku" areas near Alexandria, composed of heavy-textured soils, employing very dense drainage 0.9 m deep, drains spaced at 20 m and leaching rates equalling 30-34 thous. m^3/ha . He failed to desalinize these soils and decided to deepen drainage and to lower the ground water table.

The optimal reclamation regime is understood as such combination of irrigation and drainage when desalinization and steady improvement of the natural fertility of irrigated lands is ensured with minimal water amounts used per unit of yield.

As it is known there are distinguished four reclamation regimes - automorphic, semiautomorphic, semihydromorphic and hydromorphous.

Table 1, given below, describes the main features of the reclamation regimes.

Table 1

Main Features of Reclamation Regimes

| Nos. | Reclamation regime | Type of interaction of ground and irrigation water | Ground water supply of leading portion of water delivery, thous. m^3/ha | Ground water evaporation, thous. m^3/ha |
|------|--------------------|--|---|---|
| 1 | 2 | 3 | 4 | 5 |
| 1. | Automorphic | Irrigation water is not backed up by ground water, downward infiltration is free | $\pm \bar{\Pi} = 0.05 - 0.02 - \sum (M + T_p) - 0_c$ $M = 0$ | 0 |
| 2. | Semiautomorphic | Ground water backs up seeping irrigation water, but does not feed plants | $-\Pi \leq 0.1 - 0.2$ $\sum (M + T_p) - 0_c$ $M = 0.5 - 1.0$ | 0 - 1.5 |
| 3. | Semihydromorphic | Ground water feeds plants, prevailing over irrigation water | $-\Pi \geq 0.3 \sum (M + T_p) - 0_c$ -0_c $M \geq 2.0$ | 1.5 - 3.0 |

Table 1
(Contd.)

| 1 | 2 | 3 | 4 | 5 |
|------------------|---------------------------------------|--|--------------|---------|
| 4. Hydromorphous | Plants are mainly fed by ground water | $-\bar{H} \geq 0.8 \Sigma (K - T_p) - 0_c$ | $M \geq 5.0$ | 3.7 7.0 |

The analysis of the automorphous and other regimes has shown the increase of the total water consumption due to inefficient evaporation. The closer ground water table to the ground surface, the greater water losses by inefficient evaporation. Therefore, as far as output of water (the element of water balance) is concerned, it should be added with inefficient water losses by intensive ground water evaporation.

The value of ground water evaporation is closely associated with the leaching portion of water delivery, M . This value should be defined as the required amount of water to be added to the total irrigation rate with a view to wash away salts accumulated in the course of ground water rise. Ground water salinity being C_{TB} , inefficient ground water evaporation will result in the build-up of salts in the active layer, equalling $\Delta S_L = C_{TB} \Delta H$. In order to wash these salts away, there will be required the amount of water, M , to be determined from the formula derived by V.R.Volobuyev:

$$M \geq \alpha l_g \frac{S_n}{S_0} = \alpha l_g \left(1 + \frac{C_{TB}}{S_0} H \right) \quad (2)$$

Substituting S_0 by admissible salt accumulation in the

evaporation zone for different types of salinity and conditions, one can obtain the amount of water required for leaching the salts built up as a result of inefficient ground water evaporation.

Fig. 3 suggests the curves permitting the comparison of different reclamation regimes used in the Golodnaya Steppe proceeding from its ground water salinity equalling 6-8 g/l during the irrigation period, and similar curves for the Karshi Steppe and the Kanibadam area plotted by I.P.Aidarov, in compliance with S.F.Averyanov's methods.

It is evident that as regards reclamation, the semi automorphous regime is the most attractive one for the majority of regions whose soils are susceptible to salinization. The hydromorphous and semihydromorphous regimes can be applied to advantage when fresh confined ground water is available, for example, in zone of inundated or leveed first river terraces. The automorphous regime should be maintained on naturally drained lands or in case the possibility exists for preserving deep ground water table by sprinkling, subsoil irrigation combined with vertical drainage.

The proper choice of the reclamation regime type is essential to the reduction of the pollution of both return water and water receiving bodies (Fig. 3).

In practice the employment of the semihydromorphous regime on the lands unfavourable in terms of reclamation, results in the fact that great quantities of salts are annually involved into salt circulation through the intensive

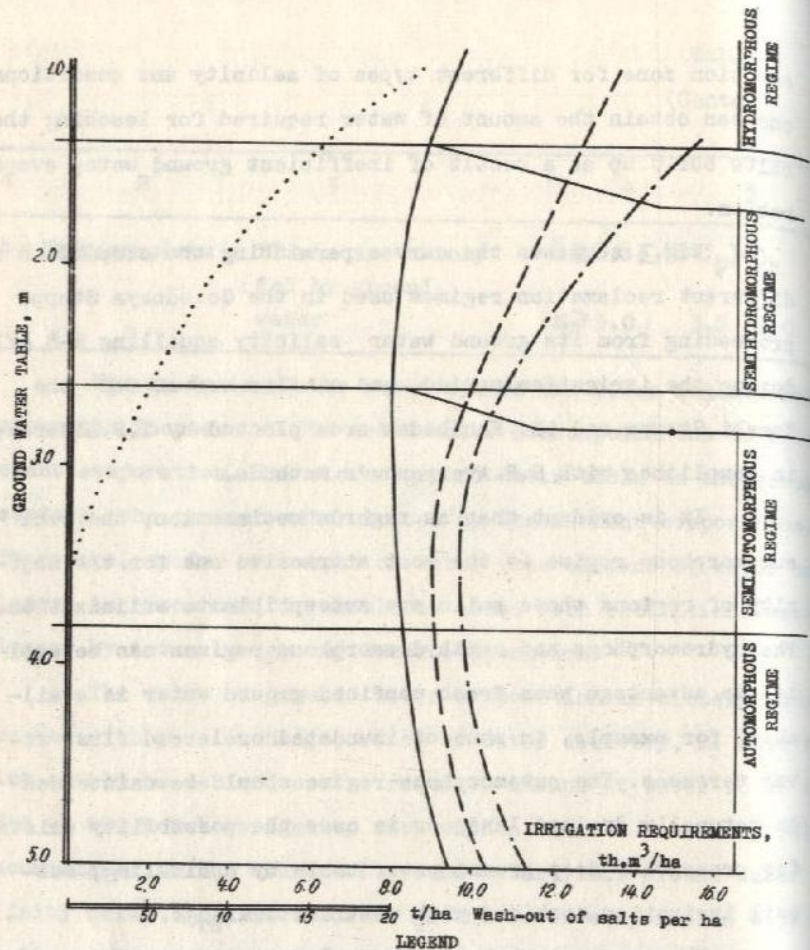


Fig. 3. Relationship between irrigation requirements, different reclamation regimes and their effect on river water pollution.

evaporation, which are to be washed away later on. Such efforts are responsible for the double harm. On the one hand, excessive amounts of water are used; on the other hand, water-receiving bodies get polluted. Thus, the proper choice of the reclamation regime permits both maximum reduction of the water amounts used for the needs of reclamation and improvement of the quality of river water.

The required reclamation regime can be achieved through a particular combination of irrigation water delivery and ground water table regulation by means of a drainage system provided at the required depth.

As regards the operation of all types of drainage, there were distinguished the leaching and operation periods. During the first period the required degree of soil desalinization is attained, conforming to the upper toxicity level when the plants are not adversely affected by salts. In the second period the leaching regime of irrigation is maintained, permitting the prevention of salt accumulation and the gradual deepening of desalinization. In case of severe soil salinity, leaching is effected using heavy rates - 10 thous. m³/ha and up, sometimes covering 2-3 seasons. Several methods of heavy-rate leaching are recognized, using: small checks, large checks and lateral leaching. The method of leaching is selected considering a slope of the location, soil properties, leaching rates. Heavy-rate leaching may be as long as 150-200 days. During the leaching period drainage operation is characterized by the higher pressure and higher values of the drainage modulus, up to 1-2 l/sec./ha. Drainage sys-

tems, built with regard for the operation period loads, are often inadequate, even though the drainage flow is increased during the leaching period, as a result of rather high pressure. Therefore, drainage systems are to be added with temporary shallow or deep open drains. Attempts are made to build temporary drainage systems by means of mole plows, protecting drain walls by polymers or thermal treatment.

Heavy-rate leachings result not only in the reduction of salt concentration in the soil but in the destruction of soil aggregates and loss of nutrients, i.e., loss of soil fertility. Thus, the experience gained in the development of heavily-saline soils in state farms No.4,5 and 6 in the Golodnaya Steppe has proved that despite the reduction of salt concentration below the upper toxicity level (0.01-0.02% according to the Cl-ion), the rates of the yield increase are very slow and 2-3 times lower compared to poorly- and medium-saline lands which have not been subjected to heavy-rate leaching (Fig.4).

Of reclamative crops grown in the USSR mention should be made of sorghum, Persian clover, joughara, Sudan grass; sesbania aculeata is popular in India, while barley, clover and other crops, in Iraq.

Reclamative crops provide better shade, decrease inefficient evaporation, enrich the soil with organic matter and nitrogen, improve the soil structure, make the soil less compact.

Of great importance is the observance of the whole complex of crop management practices, including: the time of sowing, ripping, treatment, etc. It is good practice to apply

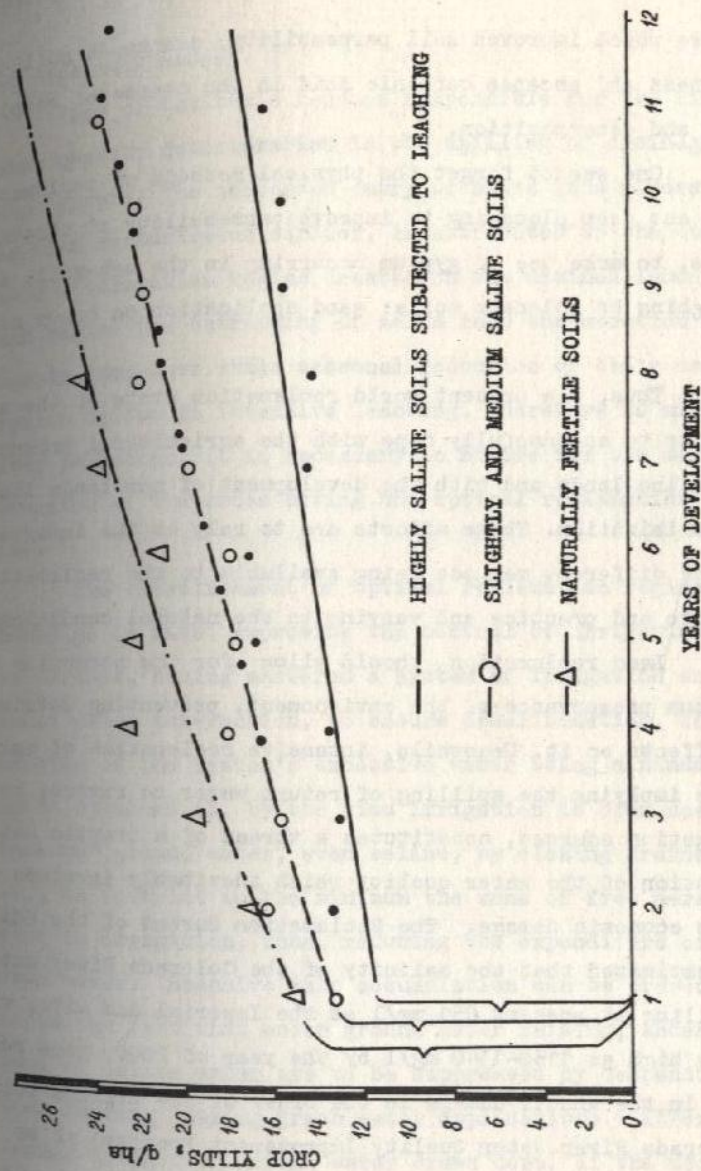


Fig.4. Averaged growth of crop yields relative to years of developing new areas in the Golodnaya Steppe.

manure which improves soil permeability, decreases soil compactness and escapes carbonic acid in the course of respiration and decomposition.

One cannot forget the physical methods of reclamation such as: deep ploughing to improve permeability of stratified soils, to make use of gypsum occurring in the sub-soil; deep ploughing on solonetz soils; sand application on heavy soils, etc.

Thus, the present world reclamation state of the art permits to successfully cope with the agricultural production on saline lands and with the development of new lands liable to salinization. These efforts are to rely on the integrated use of different methods being available to the reclamation science and practice and varying to the natural conditions.

Land reclamation should allow for the necessity of maximum preservice of the environment, preventing detrimental effects on it. Meanwhile, intensive reclamation of saline lands implying the spilling of return water to rivers, being irrigation sources, constitutes a threat of a drastic deterioration of the water quality which inevitably involves serious economic damage. The Reclamation Bureau of the USA has estimated that the salinity of the Colorado River water, equalling at present 851 mg/l at the Imperial dam site, will be as high as 1160-1340 mg/l by the year of 2000, thus resulting in the annual damage in the order of 124 million dollars (Colorado River Water Quality Improvement Program) if no urgent measures are taken. In the USSR salinity of the Syr Darya River water has markedly increased, reaching 1500 mg/l

and more at Chardara.

One of the basic reasons responsible for the river water quality deterioration is the spilling of drainage water into rivers. The increased entry of salts into rivers, as it has been demonstrated earlier, is attributed to the unfavourable reclamation regime created on the drained lands. Under such regime the entrapping of salts into the aeration zone sharply increases while seasonal reduction of their concentration is due to intensive leaching. Therefore to minimize river pollution, it is necessary to strive for the maximum extension of the areas having the optimal reclamation regime.

The establishment of optimal reclamation regimes should go in with improving the control of irrigation water so that, having mastered a system of irrigation and ground water interaction, to ensure desalinization, the spilling of the system's excessive water being minimum. This can be attained if, by the time irrigation is commenced, to "back-up" ground water, even saline, by closing drainage, i.e., to restrict to the minimum the zone of free aeration prior to irrigation, thus, reducing the expenditure of fresh water. Intensive salt accumulation can be prevented due to the fact that under ground water raising, ascending flows of saline water are to be suppressed by descending flows forming during fresh water applications. After completing irrigation ground water draws down. If the modern irrigation technique does not permit doing so, the transfer to subsoil irrigation will permit to safely reduce evaporation

losses and to regulate water delivery in the period of peak water use.

The USA and Soviet scientists suggest to lower ground water tables during the period when plants shade the surface and evaporation from the soil is considerable. This will permit to decrease salt suction to the aeration zone and later on, after intensive plants growth and plants shading the surface, to lower the ground water rise by drainage closing, because inefficient evaporation during this period is minimum (V.V. Yegorov, Shilfgard, Nilson).

River pollution can be markedly reduced through the inner-system use of drainage water. This problem was dealt with in a special paper submitted at the Symposium. The necessity of improving drainage conditions, of establishing the leaching regime in compliance with soil properties and irrigation water salinity is to be emphasized.

As to the irrigation systems known to have serious seepage losses from canals and the low efficiency of the irrigation technique, inefficient losses of irrigation water exceed 60%. This water, seeping into sedimentary rocks returns to rivers, being of quite another quality as it is loaded with salts, pesticides and chemicals which pollute again river water. Thus, the increase of the efficiency of the systems and of the irrigation technique through securing reliable seepageproof **canal linings** and improving the irrigation technique, contributes to the betterment of the quality of water in rivers. Besides, the improvement of the system efficiency by constructing canal linings, flumes and pipe-

lines, promotes the decrease of pressure created by seepage from irrigation canals on the lands whose reclamation state is known to be unfavourable, thus, reducing ground water recharge by the systems seepage water and the intensity of drainage operations.

The improvement of the technologies in land irrigation and drainage, the growth of the fleet of the machinery and the extension of our knowledge of processes and regularities of water and salt movement in the soil, their reaction with the environment enable the reclamationists all over the world to cope successfully with the task of adequate supply of the mankind with the food and raw materials.