Invariant criteria for irrigation water quality assessment in arid and semiarid regions

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INVARIANT CRITERIA FOR IRRIGATION WATER QUALITY ASSESSMENT IN ARID AND SEMIARID REGIONS

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Introduction

A lot of classifications are proposed for the assessment of irrigation water quality. Most of them are based on considera-tion of bulk salt concentrations and relationships between cation concentrations (i.e. SAR). Some of classifications in-clude values of electrical conductivity. But these values clo-sely correlate with a sum of cations.

Surface water composition is subjected to seasonal and spa-tial variability. Seasonal changes are partly or mostly connec-ted with evaporation and dilution of water. During a year the same water sourse can supply irrigation waters which belong to different cation-based water quality classes.

In spite of such variability some general regularities of salinization have been registered for many regions (Szabolcs, Kovda, 1979). Therefore from practical point of view it is desi-rable to adopt some criteria which reflect the regional pequ-larities but only in minor part are influenced by year cycle changes (first of all caused by evaporation and dilution).

Aims of this work were: 1) to propose a set of invariant pa-rameters of irrigation water composition; 2) to use such pa-rameters for an introducing of several wide irrigation water families which should include water composition of arid and semiarid zones; 3) to enlist land reclamation problems and their typical solutions for different water families.

The concept

The introduction of invariant water quality criteria is based on the assumption that in arid and semiarid regions eva-porative concentrating is a dominanting process of water quali-ty transformation. Precipitation of any salt leads to substrac-tion of equivalent amounts of corresponding cations and anions from the solution composition. The effect of water on irrigated soil is connected with the composition of solution formed at the last stages of evaporation process. The generalized defini-tion of inorganic alkalinity is used for water quality criteria construction:

$$Alk = (Ca) + (Mg) + (Na) + (K) - (Cl) - (NO_3) - (SO_4)$$

Here ion concentrations, me/l, are given in parentheses. Several parameters are invariant with the respect to evaporation and dilution of the water. For example a value of $R_1 = Alk - (Ca)$ does not change during calcium carbonate precipitation. It is known as a "residual calcium carbonate alkalinity" (Eaton, 1950). Another parameter $R_2 = Alk - (Ca) + (SO_4)$ will not be changed in the case of calcium carbonate and calcium sulphate precipitation. This value was introduced as "residual calcium carbonate - calcium sulphate alkalinity" (Droubi, 1976). Third parameter under consideration is $R_3 = (SO_4) - (Na)$. Positive value of R_3 reflects a presence of sodium hydrocarbonate in the solution which is formed as a result of calcium salts precipitation after evaporation of the water.

Signs of the alkalinity and R_1, R_2, R_3 values show possible precipitation sequences as well as effects of transformed waters on soils. For example the inequality $Alk > 0$ is the precondition of $CaCO_3$ precipitation during the evapor: ive consentrating, the inequality $R_1 < 0$ is the precondition of gypsum precipitation, etc. It leads us to the consideration of R_1, R_2, R_3 values as approximately invariant criteria of irrigation water quality. According to those criteria waters of arid and semiarid regions can be subdivided in a following way:

$Alk < 0$	$Alk > 0$			
Acid group	$R_1 < 0$ Saline group		$R_1 > 0$ Alkaline group	
	$R_2 < 0$	$R_2 > 0$	$R_3 < 0$	$R_3 > 0$
(1)	(2)	(3)	(4)	(5)
Acid family	Calcic saline family	Sulphate saline family	Sulphate alkaline family	Carbonate alkaline family

A database on irrigation water composition has been compiled for further investigations. It containes 10,000 chemical analyses data from different parts of the World. All data were assesed from point of view of above mentioned criteria gradationes.

Computer program LIBRA has been used for evaluation of enfluence of natural processes on water quality transformation.

Results and discussion

Processing of database has shown that waters of the same source mostly don't change the family during irrigation season. On the contrary the water from the same source moves from one class of cation composition-based classifications to another one during the year (for example in Kouroumari region, Mali, up to three classes).

When passing through calcium containing sediments waters can change the family (waters from foothills of Elburz in Iran can be taken as an example). Irrigation water reclamation usually transfers waters from one family to another.

In relatively homogeneous regional climatic and geological conditions the only water family is usually presented. In general the type of climate is the governing factor of the water family formation on the global level. But geological conditions and the vegetation can influence significantly in regions. The boundary situations with R_1 near 0 and/or R_2 near 0 are not rare for semiarid regions (waters from Trans-Volga region in USSR, Ebra valley in Spain, pampa territories in Argentina).

It is worthy to mention that in some cases irrigation water transformation can be partly induced by cation exchange as well as by some biological processes (sulphate reduction, denitrification). If the cation exchange is important then critical values of "residual alkalinities" are not equal to zero at borders between families. Data analysis and calculations of chemical equilibria in soils using computer program "LIBRA" have shown that a transfer from saline to alkaline group occurs with R_1 value near to 0.15 me/l at low levels of sum of cations (S) = near [illegible] me/l. But at S=10 the boundary value R_1 becomes close to 0. The transfer from family 2 to family 3 takes place at R_2 near [illegible] me/l at S=10me/l and R_2 near to 0 at S=20 me/l.

Waters of the same family create similar land reclamation problems in different regions of the World. The similarity of problems leads to similarity of basic solutions. Using waters of the family (1) one can face with high acidity, overwetting and salinity. Drainage, leaching and alkaline amendments lead to positive results. Waters of the family 2 are usual for regions where salinity is the main problem. A stabilization of productivity can be achieved by the use of leaching (combined with drainage, if possible). Waters of family 3 are applied in salinity affected regions too. Low salt content waters of this family sometimes can be hardly applied directly due to bad soil permeability. Waters of the family 4 are typical for regions where main problems arise with bad physical properties of soils. The sufficient results can be obtained with the use of chemical amendments - acid as $FeSO_4$, FeS, etc, or calcium containing as gypsum, phosphogypsum, etc. The heaviest problems are connected with waters of the family 5. Chemical reclamation of soils and waters in this case is a necessary but often not sufficient affair. Additional reclamation technique is unavoidable (Gill, Abrol, 1990).

Proposed criteria reflect regional trends of irrigation influence on soils. A degree of trend development can be estimated using local cation-based criteria.

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