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सिंचाई के पानी की गुणता हेतु — मार्गनिर्देश

(पहला पुनरीक्षण)

Quality of Irrigation Water — Guidelines

(First Revision)

ICS 13.060.01

भारतीय मानक ब्यूरो
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FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Farm Irrigation and Drainage Systems Sectional Committee had been approved by the Food and Agriculture Division Council.

The quality of irrigation water is to be evaluated in terms of degree of harmful effects on soil properties with respect to the soluble salts it contains in different concentrations and crop yield. To evaluate the quality of irrigation water, this standard has been formulated as a guideline for advisory purposes.

The standard was first published in 1986. This revision has been undertaken to incorporate the following:

a) Grouping of poor quality ground water for irrigation in India.
b) Consideration of additional toxic elements such as sodium, fluoride, chloride and heavy metals such as selenium, cadmium, lead and arsenic, etc.
c) Water quality in relation to improved irrigation techniques.
d) Suitability of poor quality high saline and alkali ground waters for irrigation in India.
e) Upper permissible concentrations of trace elements in irrigation water.
f) Relative tolerance of crops to alkali stress.

In the formulation of this standard, considerable assistance has been derived from the Central Soil Salinity Research Institute, Karnal, Indian Institute of Water Management, Bhubaneshwar and Water Technology Centre, Indian Agricultural Research Institute, New Delhi.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value observed or calculated, expressing the result of a test or analysis shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

QUALITY OF IRRIGATION WATER — GUIDELINES

(First Revision)

1 SCOPE

This standard prescribes the guidelines for assessing the quality of irrigation water.

2 REFERENCES

The following standards contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

IS No.	*Title*
7022 (Part 1) : 1973	Glossary of terms relating to water, sewage, industrial effluents: Part 1
7022 (Part 2) : 1979	Glossary of terms relating ot water, sewage, industrial effluents: Part 2
7022 (Part 3) : 2018	Glossary of terms relating to water: Part 3 Marine water and related methods
11077 : 1984	Glossary of terms on soil and water

3 DEFINITION

For the purpose of this standard the definitions given in IS 7022 (Part 1), IS 7022 (Part 2), IS 7022 (Part 3), and IS 11077 shall apply.

4 SUITABILITY CRITERIA

4.1 The suitability of irrigation water depends upon several factors, such as, water quality, soil type, plant characteristics, irrigation method, drainage, climate and the local conditions. The integrated effect of these factors on the suitability of irrigation water (SI) can be qualitatively expressed by the relationship:

$$SI \propto QSPCD$$

where

Q = quality of irrigation water, that is, total salt concentration, relative proportion of cations/anions, etc;

S = soil type, texture, structure, permeability, fertility, calcium carbonate content, type of clay minerals and initial level of salinity and alkalinity before irrigation;

P = salt tolerance characteristics of the crop and its varieties to be grown, and growth stage usually categorized as tolerant, semi-tolerant and sensitive;

C = climate, that is the total rainfall, its distribution and evaporation characteristics; and

D = drainage conditions, depth of water table, nature of soil profile, presence of hard pan or lime concentration and management practices.

4.1.1 These factors act interactively. For example; in a particular climate, all factors enumerated in **4.1**, are likely to vary and interact either positively or negatively in relation to salt accumulation and degree of harmful effect on soil properties and crop growth. As such, a single suitable criterion is hard to be adopted for widely varying conditions. However, general broad guidelines have been developed for use by the field practitioners.

4.2 Besides these factors, presence of some ions in water such as calcium, sulphate, potassium and nitrate is favourable for crop growth, as water of more salinity can be used in the presence of these ions.

5 WATER QUALITY CRITERIA FOR IRRIGATION

5.1 The following chemical properties shall be considered for developing water quality criteria for irrigation:

a) Total salt concentration;
b) *p*H;
c) Sodium adsorption ratio;
d) Residual sodium carbonate or bicarbonate ion concentration; and
e) Toxic elements such as sodium, boron, fluoride, chloride and heavy metals, etc.

Though all the chemical characteristics are determined separately, these are present in varying amounts in each type of irrigation water. The chemical characteristics interact with each other and cause hazardous effects on soil properties and crop growth. As such the Electrical Conductivity (EC), Sodium Absorption Ratio (SAR) and Residual Sodium Carbonate (RSC) are considered together in classifying the water. The dominating character would determine the characteristics as well as management option although management options for the other character would also be required simultaneously. For example, a water of high EC may have high SAR or RSC or boron or silica. In that event, gypsum may be required even for saline water having SAR > 20 or rich in silica.

5.1.1 *Total Salt Concentration*

It is expressed as the electrical conductivity (EC), in relation to hazardous effects of the total salt concentration. The irrigation water can be classified into two major groups that is marginally alkali and tonic (*see* Table 1).

5.1.2 *p*H

*p*H is an indicator of the acidity or alkalinity of a water, but is seldom a problem by itself for surface irrigation. The main use of *p*H in a water analysis is to detect abnormal water. An abnormal value not falling within 6.5 to 8.4 *p*H range is a warning that the water needs further evaluation as it may cause a nutritional imbalance or may contain a toxic ion. However, *p*H correction plays a very important role in minimizing the clogging of drippers for which a *p*H less than 7 is recommended.

5.1.3 *Sodium Adsorption Ratio (SAR)*

It shall be calculated from the following formula:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{(Ca^{2+} + Mg^{2+})}{2}}}$$

where

SAR = sodium adsorption ratio (millimole/litre)$^{1/2}$
Na^{+} = sodium ion concentration, me/litre;
Ca^{2+} = calcium ion concentration, me/litre; and
Mg^{2+} = magnesium ion concentration, me/litre.

NOTE — me/l = milliequivalent/litre.

In case the concentration of Na, Ca and Mg ions is expressed in terms of millimole/litre, then the equation for SAR could be written as:

$$SAR = \frac{Na^{+}}{\sqrt{(Ca^{2+} + Mg^{2+})}}$$

In relation to the hazardous effects of sodium adsorption ratio, the irrigation water quality rating is given in Table 1. When SAR is more than 10, it could be high SAR saline or high SAR alkali depending upon the EC or RSC of the irrigation water (*see* Table 1).

5.1.4 *Residual Sodium Carbonate (RSC*)

It shall be determined by the equation:

$$RSC = (CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})$$

where

RSC = residual sodium carbonate (me/l),
CO_3^{2-} = carbonate ion concentration (me/l),
HCO_3^{-} = bicarbonate ion concentration (me/l),
Ca^{2+} = calcium ion concentration (me/l), and
Mg^{2+} = magnesium ion concentration (me/l).

In relation to the hazardous effects of high carbonate/bicarbonate ions concentration expressed as RSC, the irrigation water quality rating is given in Table 1. The high RSC is an indicator that SAR of the water in the soil solution might increase due to precipitation of calcium.

5.1.5 *Mg/Ca Ratio*

Besides the three parameters EC, SAR and RSC, water quality is affected by individual ions as well. Since Mg is considered to be an intermediate ion that is not as harmful as Na and not as good as Ca, excess of Mg as revealed by the Mg/Ca ratio is considered while using guidelines given in Table 3. If Mg/Ca ratio is more than 3.0 addition of gypsum is required to minimize the Mg on the exchange complex of the soils. However, calcium: magnesium ratio above 2.0 in water is beneficial.

5.1.6 *Cl/SO$_4$ Ratio*

Cl salinity is more harmful than the salinity due to SO_4 ions. If Cl/SO_4 ratio is more than 2, additional steps are required to minimize the harmful effect of chloride ions. On the other hand, sulphate: chloride ratio of more than 2.0 is beneficial. Chloride concentration in itself could be toxic beyond 75 mg/l causing severe problems when it exceeds 350 mg/l.

Table 1 Grouping of Poor Quality Ground Water for Irrigation in India
(*Clauses* 5.1.1 *and* 5.1.3)

Sl No.	Water Quality	ECiw (dS/m)	SARiw (millimole/litre)$^{1/2}$	RSC (me/l)
(1)	(2)	(3)	(4)	(5)
i)	Good	< 0.7	< 10	< 2.5
ii)	Saline:			
	a) Marginally saline	0.7 to 3.0	< 10	< 2.5
	b) Saline	> 3	< 10	< 2.5
	c) High-SAR saline	> 3	> 10	< 2.5
iii)	Alkali water:			
	a) Marginally alkali	< 4	< 10	2.5 – 4.0
	b) Alkali	< 4	< 10	> 4.0
	c) High-SAR alkali	Variable	> 10	> 4.0
iv)	Toxic water	The toxic water has variable salinity, SAR and RSC but has excess of specific ions such as chloride, sodium, nitrate, boron, fluoride, or heavy metals such as selenium, cadmium, lead and arsenic, etc		

5.1.7 *Toxic Water*

These waters have variable EC, SAR and RSC but excess of an individual ion that causes toxicity to plants resulting in reduced crop growth/yield. The ions could be chloride, sodium, nitrate, boron, fluoride, or heavy metals such as selenium, cadmium, lead and arsenic etc. Although N is quite useful nutrient for the growth of plants, waters with high N can cause quality problems in crops such as barley and sugar beets and excessive vegetative growth in others affecting their productivity.

Compensation in N is therefore, recommended when the N concentration exceeds 10 ppm NO_3-N (45 ppm NO_3).

Toxic waters need to be tested for specific ions as per location specific requirements.

5.1.7.1 *Boron content*

Boron, though a nutrient, becomes toxic if present in water beyond a particular level. In relation to boron toxicity, the irrigation water quality rating is given in Table 2.

Table 2 Water Quality Rating Based on Boron Content
(*Clause* 5.1.7.1)

Sl No.	Class	Boron (mg/l)
(1)	(2)	(3)
i)	Low	Below 1.0
ii)	Medium	1.0 – 2.0
iii)	High	2.0 – 4.0
iv)	Very high	Above 4.0

5.1.8 *Water Quality in Relation to Improved Irrigation Techniques*

Sprinkler and drip irrigation systems are fast expanding and the water quality requirement for these systems could be vastly different than for surface irrigation techniques. Iron concentrations of less than 0.3 ppm are required for micro-irrigation systems, since iron in water become oxidized to insoluble forms that could cause black or brown stains on foliage of plants if used with sprinkler irrigation. Similar case is with manganese. High chloride concentrations can cause leaf burn when applied with sprinkler irrigation. For sprinkler irrigation bicarbonate less than 1.5 me/l does not pose much problems but the problems increase and become severe when the bicarbonate content is 8.5 me/l.

Concentrations of ferrous iron as low as 0.15 - 0.20 mg/l are considered as a potential hazard for clogging of drip systems. Emitter clogging hazard is moderate for concentrations between 0.2-1.5 mg/l. Concentrations above 1.5 mg/l are considered to cause severe clogging problems. Concentrations of manganese should be < 0.10 mg/l for no problem and the severe problems would be experienced when concentration exceed 1.5 mg/l.

The phosphoric acid used as phosphorous fertilizer could react with available calcium in water and form insoluble phosphate, which precipitate leading to clogging of drippers. Under these conditions *p*H of the water should be decreased below 7 (*see* **4.1.2**) by using high dose of phosphoric acid in the water tank to avoid precipitation of phosphates.

6 WATER QUALITY RATING IN RELATION TO SOIL TYPE, RAINFALL AND CROP TOLERANCE TO SALTS

6.1 Guidelines for the upper permissible limit of electrical conductivity (EC) are given in Table 3 keeping in view the soil types, rainfall and three types of crops, that is Sensitive (S), Semi-tolerant (ST) and Tolerant (T).

Table 3 Suitability of Poor Quality Saline Ground Waters (RSC < 2.5 me/l, SAR <10 $(mmol/l)^{1/2}$ for Irrigation in India
(*Clauses* 5.1.5 *and* 6.1)

Sl No	Soil Texture Group	Crop Tolerance	ECiw(dS/m) Limit for Rainfall (mm) Region		
			< 350	350 – 550	> 550
(1)	(2)	(3)	(4)	(5)	(6)
i)	Fine	S	1.0	1.0	1.5
ii)	(>30 percent clay)	ST	1.5	2.0	3.0
iii)	Sandy clay, clay loam, silty clay loam, silty clay, clay	T	2.0	3.0	4.5
iv)	Moderately fine	S	1.5	2.0	2.5
v)	(20 to 30 percent clay)	ST	2.0	3.0	4.5
vi)	Sandy clay loam, loam, silty loam	T	4.0	6.0	8.0
vii)	Moderately coarse	S	2.0	2.5	3.0
viii)	(10 to 20 percent clay)	ST	4.0	6.0	8.0
ix)	Sandy loam, loam, silty loam	T	6.0	8.0	10.0
x)	Coarse	S	--	3.0	3.0
xi)	(<10 percent clay)	ST	6.0	7.5	9.0
xii)	Sand, loamy sand, sandy loam, silty loam, silt	T	8.0	10.0	12.5

NOTE — (a) The use of waters of 4.0 dS/m EC and above be confined to winter season crops only. They should not be used during the summer season. During emergencies not more than one or two protective irrigations should be given to the *kharif* season crops. (b) For soils having (i) shallow water table (within 1.5 m in *kharif*) and (ii) presence of hard subsoil layers, the next lower EC_{iw} is applicable.

6.2 Upper permissible limits of sodium adsorption ratio (SAR) and residual sodium carbonate(RSC) for various soil textures is given in Table 4. Lower limits of RSC are used for semi-tolerant while upper limits for sodicity tolerant crops.

6.3 The upper permissible limits of boron for ST and T crops are given in Table 5.

6.4 Upper permissible limits of various toxic ions and elements are reported in Table 6.

7 SALT TOLERANCE OF CROPS

There are intra-generic and inter-generic differences in salt tolerance of crops and thischaracter of crops and crop varieties could be exploited to use poor quality water. The data presented in Tables 7, Table 8 and Table 9 presents the relative tolerance of salts to soil salinity, soil alkali and boron. These tables could be used to select crops depending upon the kind and degree of the problem with water.

Table 4 Suitability of Poor Quality High SAR Saline And Alkali Ground Waters (RSC > 2.5 me/l, EC_{iw}< 4.0 dS/m) for Irrigation in India

(*Clause* 6.2)

Sl No.		SAR (mmol/l)1/2		Upper limits of RSC (me/l)		Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
		ST	T	ST	T	
i)	**Fine** (>30 % clay) Sandy clay, clay loam, silty clay loam, clay silty clay,	10	15	2.5	3.5	Limits pertain to *kharif*fallow/*Rabi* crop rotation when annual rainfall is 350-550 mm.
ii)	**Moderately fine** (20 to 30 % clay) Sandy clay loam, loam, silty loam	10	3.5 – 5.0			When the waters have Na < 75%, (Ca+Mg>25%) or rainfall is >550 mm, even the RSC values for tolerant crops becomes safe for ST crops.
iii)	**Moderately coarse** (10 to 20 % clay) Sandy loam, loam, silty loam	15	5.0 – 7.5			Grow low water requiring crops During*kharif*. Avoid rice/sugarcane. Presence of gypsum in soil is favourable
iv)	**Coarse** (> 10) Sand, loamy sand, sandy, loam, silty, loam, silt	20	7.5 –10.0			

Table 5 Suitability of Irrigation Water for Semi-Tolerant and Tolerant Crops in Different Soil Types

(*Clause* 6.3)

Sl No.	Soil Textural Group	Upper Permissible Limit of Boron (mg/l)	
		ST	T
(1)	(2)	(3)	(4)
i)	Fine (Above 30 % clay) sandy clay, clay loam, silty clay loam, silty clay, clay	2	3
ii)	Medium (20-30 % clay) sandy clay loam, loam, silty loam	2	3
iii)	Moderately coarse (10-20 % clay) sand, loamy sand, silty loam	2	3
iv)	Coarse (< 10 % clay) sand, loamy sand, sandy loam, silty loam, silt	1	2

Table 6 Upper Permissible Concentrations of Trace Elements in Irrigation Water

(*Clause* 6.4)

Sl No.	Element	Recommended Maximum Concentration (mg/l)	Remarks
(1)	(2)	(3)	(4)
i)	Al (Aluminium)	5.0	Can cause non-productivity in acid soils (*p*H < 5.5), but more alkaline soils at *p*H > 7.0 will precipitate the ion and eliminate any toxicity.
ii)	As (Arsenic)	0.10	Toxicity to plants varies widely, ranging from 12 mg/l for Sudan grass to less than 0.05 mg/l for rice.
iii)	Be (Beryllium)	0.10	Toxicity to plants varies widely, ranging from 5 mg/l for kale to 0.5 mg/l for bush beans

Table 6 — (*Concluded*)

(1)	(2)	(3)	(4)
iv)	Cd (Cadmium)	0.01	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solutions. Conservative limits recommended due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans.
v)	Co (Cobalt)	0.05	Toxic to tomato plants at 0.1 mg/l in nutrient solution. Tends to be inactivated by neutral and alkaline soils.
vi)	Cr (Chromium)	0.10	Not generally recognized as an essential growth element. Conservative limits recommended due to lack of knowledge on its toxicity to plants.
vii)	Cu (Copper)	0.20	Toxic to a number of plants at 0.1 to 1.0 mg/l in nutrient solutions.
viii)	F (Fluoride)	1.0	Inactivated by neutral and alkaline soils.
ix)	Fe (Iron)	5.0	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of availability of essential phosphorus and molybdenum. Overhead sprinkling may result in unsightly deposits on plants, equipment and buildings
x)	Li (Lithium)	2.5	Tolerated by most crops up to 5 mg/l; mobile in soil. Toxic to citrus at low concentrations (<0.075 mg/l). Acts similarly to boron.
xi)	Mn (Manganese)	0.20	Toxic to a number of crops at a few-tenths to a few mg/l, but usually only in acid soils.
xii)	Mo (Molybdenum)	0.01	Not toxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high concentrations of available molybdenum
xiii)	Ni (Nickel)	0.20	Toxic to a number of plants at 0.5 mg/l to 1.0 mg/l; reduced toxicity at neutral or alkaline *p*H.
xiv)	Pb (Lead)	5.0	Can inhibit plant cell growth at very high concentrations
xv)	Se (Selenium)	0.02	Toxic to plants at concentrations as low as 0.025 mg/l and toxic to livestock if forage is grown in soils with relatively high levels of added selenium. An essential element to animals but in very low concentrations
xvi)	Sn (Tin)		
xvii)	Ti (Titanium)	—	Effectively excluded by plants; specific tolerance unknown
xviii)	W (Tungsten)		
xix)	V (Vanadium)	0.10	Toxic to many plants at relatively low concentrations
xx)	Zn (Zinc)	2.0	Toxic to many plants at widely varying concentrations; reduced toxicity at *p*H > 6.0 and in fine textured or organic soils.

Table 7 Crop Groups Based on Response to Soil Salinity
(*Clause* 7)

Sl No.	Sensitive Group		Resistant Group	
	Highly Sensitive	Medium Sensitive	Medium Tolerant	Highly Tolerant
(1)	(2)	(3)	(4)	(5)
i)	Lentil	Radish	Spinach	Barley
ii)	Mash	Cow pea	Sugarcane	Cotton
iii)	Chickpea	Broad bean	Indian mustard	Sugar beet
iv)	Beans	Vetch	Rice (transplanted)	Turnip
v)	Peas	Cabbage	Wheat	Tobacco
vi)	Carrot	Cauliflower	Pearl millet	Safflower
vii)	Onion	Cucumber	Oats	Rapeseed
viii)	Lemon	Gourds	Alfalfa	Karnal grass
ix)	Orange	Tomato	Blue panic grass	Date palm
x)	Grape	Sweet potato	Para grass	Ber
xi)	Peach	Sorghum	Rhodes grass	*Mesquite*
xii)	Plum	Minor millets	Sudan grass	*Casuarina*
xiii)	Pear	Maize	Guava	*Tamarix*
xiv)	Apple	Clover, *berseem*	Pomegranate	*Salvadora*
xv)			*Acacia*	

Table 8 Relative Tolerance of Crops to Alkali Stress
(*Clause* 7)

Sl No.	Characteristics	ESP Range[1)]	Crops
(1)	(2)	(3)	(4)
i)	Sensitive	10-15	Safflower, mash, peas, lentil, pigeon pea, urdbean
		16-20	Chickpea, soybean
		20-25	Groundnut, cowpea, onion, pearl millet
ii)	Semi-tolerant	25-30	Linseed, garlic, *guar*
		30-50	Indian mustard, wheat, sunflower
iii)	Tolerant	50-60	Barley, *Sesbania*
		60-70	Rice (Transplanted)

[1)] Relative yields are only 50 percent of the potential in respective alkali range.

Table 9 Relative Tolerance of Crops to Boron
(*Clause* 7)

Sensitive (<1 mg/l)	Semi-Tolerant (1.0-2.0 mg/l)	Tolerant (2.0-4.0 mg/l)
Apple	Sunflower	Date palm
Grape	Potato	Sugar beet
Cherry	Cotton	Garden beet
Peach	Tomato	Alfalfa
Orange	Radish	Gladiolus
Grapefruit	Field pea	Broad bean
Lemon	Barley	Onion
	Wheat	Turnip
	Corn	Cabbage
	Rice	Lettuce
	Oat	Carrot
	Bell pepper	Cauliflower
	Sweet potato	

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