WATER SUPPLY FOR AGRICULTURE

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Summary

Natural water resources represent a vital biosphere component—an economic and industrial resource that possesses indispensable consumer properties. Water pollution and water ecosystems degradation are increasing global problems which affects all aspects of human activity and influences human health, economics and social conditions. Water consumption on Earth during the twentieth century increased sevenfold while the population only increased three times. Agriculture is the greatest world water consumer. Development of agriculture including irrigation requires 65% of the total world water consumption. Water quality is the most important factor of ecological safety and stability in agriculture development.

The quality of water used to supply rural units, cattle-breeding complexes and farms influences human health, stock viability and productivity, and the quality and safety of agriculture products. One of the main problems in supplying water for agriculture is the disconnectedness of rural units, cattle-breeding complexes, farms and pastures, often over a vast area in arid regions. The requirements for water quality for stock differ depending on the species, age, daily demand for each species, and the chemical elements added to stock feed in order to increase their weight and to decrease disease risk. Water in the supply system of rural units and farms should be ecologically safe for animals and human beings.

The chemical composition of irrigation water in agriculture influences soil productivity,

water consumption, crop productivity, quality of agricultural products and, therefore, human health. Water quality also influences the durability and reliable functioning of irrigation systems. Irrigated agriculture causes formation of a complex water-nutrition system: “water–soil–plants–stock–humans”. Pollutants are accumulated during each stage of this system; they may be transformed, either increasing or losing toxicity. In accordance with this, we describe principles of regulation, criteria and quality evaluation for irrigation water. The quality evaluation system of irrigation water permits evaluation of a water source with regard to risk of salinization, solonetzization, contamination of soils by heavy metals and pesticides, risk of corrosion, carbonate formation, algal blooms and choking of irrigation system elements.

Standardization of water quality is a key part of ecological safety and stability in agriculture, and an essential component of the complex of practical actions and mechanisms (economic, legislative, legal and technological) for realization of ecosystem water use in agriculture.

1. Introduction

At the end of the twentieth century, pollution and degradation processes in soils, surface and underground waters acquired high importance and a global dimension. Disorders in humans and animals, degradation of landscape and water ecosystems, decrease in productivity and quality of agricultural products demand an understanding of the role of water quality in these processes and creation of a unified system of ecological standardization of water quality use in agriculture. Due to increasing pollution of surface and underground water, modern agriculture is increasingly dependent on the quality of water used for industrial and domestic purposes, as well as development of stockbreeding and irrigation. Rural regions need water of a quality not less than that used in towns. This is most essential for drinking water and for water used in dairy production. Quality evaluation of water used for watering of stock has certain inherent problems due to the need to take account of factors such as quantity of water consumed by the animal, animal sex, age and size. Complex multifactor water-nutrition systems are created in irrigated cultivation: “water–soil–plants–animals–humans”, and “water–soil–underground water–humans”. Pollutants are accumulated in each stage of the system and may be transformed, either increasing or reducing in toxicity. Standardization of water quality in agriculture is therefore one of the most important factors of ecological safety and stable development of agriculture.

2. Water supply of rural units

Requirements for water quality in agricultural water supply are usually considered and evaluated separately for centralized industrial-drinking water systems comprising a complex of water supply stations, including saw-setting, non-centralized (local) systems with saw-setting water supply net systems and non-centralized systems without saw-setting networks.

Sanitary requirements for drinking water quality are based on safety conditions with regard to epidemiology, chemical composition, and organoleptic properties, and are the same for both urban and rural populations. The requirements for drinking water quality described in *Drinking Water Supply* are fully extended to water supplied by centralized systems for agricultural water supply. It is more difficult to provide delivery of water of required quality for agriculture than for urban municipal supplies because of the specific conditions of agricultural water supply (large geographical areas, dislocation of units, many of which are located in arid regions, and problems with qualified service personnel, instrumentation and equipment supply). As a result of the long lengths of pipelines, high pipe pressure, and difficult operating conditions, water quality is reduced, especially in the early stages: the content of iron and lead is increased, unpleasant odors appear, the water color index may increase, bacterial contamination increases, and fluorine content decreases. The deterioration of water quality en route from the source to the consumer poses additional requirements for systems of water quality checking and control.

Non-centralized industrial-drinking water systems, comprising both those with and without saw-settings, are common in water supplies of rural units and farms. Dug and drilled wells and springs are used, as well as surface water sources and imported water, ad these often contain undesirable impurities. Solid particles in water may be of organic and inorganic origin. Particles of inorganic origin include sand, mud and clay particles. Dissolved inorganic salts and mineral substances may be found both in surface and underground waters. Surface waters flowing down from catchments contain dissolved organic substances. Stagnant water is prone to growth of algae, including diatoms, and protozoa that impart an unpleasant odor and taste to water. Unpleasant odors are often due to the presence of sulfate-reducing bacteria in water. Growth of iron bacteria in pipes results in formation of slimy deposits that may cause pipe systems to clog, as well as unpleasant odors. Insufficient protection of non-centralized industrial-drinking water systems requires additional measures of control, purification and adjustment of drinking water quality in order to meet the stated levels.

3. Water quality in cattle breeding

Requirements provided for water quality used in watering of stock take into account animal species, animal age, daily water consumption for each species, chemical elements added to animal feed for faster weight growth and for decrease of diseases risk, as well as information about toxicity of particular substances for each species. Water used in watering of stock should be transparent, colorless, and without any foreign odors or tastes. It should not contain decay products of organic substances, toxic chemical impurities, pathogenic microorganisms or helminth cysts.Temperature of water used for animals is of great importance as a physiological factor. For adult stock the temperature should be between 8 and 20 °C, and for young stock, from 15 to 30 °C. Low water quality has a negative influence on stock, causing diseases, reducing optimal stock weight, and resulting in milk and meat unsuitability.

The most important water quality indexes are mineralization, chlorides, sulfates (Table 1), nitrates, some heavy metals and pesticides (Table 2).

Species	**Age group**	**Dry residue g l^{-1}**	**Content of mineral ingredients in water composition, g l^{-1}**	**Total hardness, mg equiv**

			chlorides	sulfates	l^{-1}
Cattle	grown up stock young stock	0.8/2.4 0.60/1.8	0.12/0.6 0.10/0.4	0.25/0.8 0.20/0.6	10/18 10/14
Sheep, goats	grown up stock young stock	1.0/5.0 0.5/1.0	0.7/2.0 0.5/1.5	0.8/2.4 0.6/1.7	24/45 20/30
Pigs	grown up stock young stock	0.6/1.0 0.5/1.0	0.1/0.4 0.1/0.35	0.2/0.6 0.18/0.5	8/14 8/12
Horses	grown up stock young stock	0.5/1.0 0.4/1.0	0.1/0.4 0.08/0.35	0.15/0.5 0.12/0.5	10/15 10/12

Note: numerator represents optimal values of indexes; denominator represents the maximum permissible values.

Table 1. Water mineralization standards for watering of animals

Indexes	**Maximum permissible concentration, mg l^{-1}**		**Indexes**	**Maximum permissible concentration, mg l^{-1}**
Aluminum	5.0		Volatile phenols	0.01
Arsenic	0.05		Anionic detergents	0.5
Beryllium	0.1		Cyanides (total)	0.5
Boron	5.0		**Pesticides:**	
Cadmium	0.02		Atrazine	0.06
Chromium	0.1		Bromoxynil	0.019
Cobalt	1.0		Captan	0.02
Copper	1.0		Carbofuran	0.045
Fluorine	2.0		Cyanazin	0.01
Lead	0.1		Dicamba	0.069
Mercury	0.001		Diclofop-methyl	0.009
Molybdenum	0.5		Dynoseb	0.15
Nickel	1.0		Dimethoate	0.004
Nitrate + nitrite (NO_3-N, NO_2-N)	100.0		Glyphozate	0.28
Selenium	0.05		Lindane	0.004
Uranium	0.2		Metachlor	0.05
Vanadium	0.1		Methrybuzin	0.08
Zinc	24.0		Picloram	0.19
Iron	1.5		Simazin	0.01
Petroleum derivatives	0.05		Triallat	0.23
Ammonium	0.5		Trifluralin	0.045

Manganese	0.05		2,4-D	0.1

Table 2. Standards for pollutant substances in water for watering of animals

The maximum permissible content of magnesium in water used for watering of animals is of 250 mg×l^{-1}, and for adult sheep fed by dry feed, 500 mg×l^{-1}. The permissible pH range of water is from 6.5 to 9.0; the coli-titer is 50 ml, and coli-index less than 10.

When evaluating the utility of water sources for watering of animals, the following factors should be taken into account:

- small shallow wells and springs are characterized by a higher probability of water pollution than big wells and rivers;
- groundwaters have a more distorted chemical composition than that of surface sources;
- during hot dry periods water may become unsuitable due to higher evaporation, higher temperature, and changes in ionic composition;
- dry feed and high-level protein additives, instead of the formerly used green biomass, may decrease salt tolerance of animals due to the lower amount of water and higher content of salts in the feed.

4. Water quality in irrigation

The total area of irrigated lands increased from 50 billion hectares in 1900 to 250 billion hectares at the end of the twentieth century. The irrigated land, although representing only 16% of the total agricultural area, provides 40% of total world food production. The quality and quantity of agricultural products, and therefore the welfare and health of the human population on Earth is very dependent on the quality of water used in irrigation.

At the beginning of the twentieth century, Russia and USA identified the problem of quality standardization for irrigation water, and they demonstrated the risks resulting from soil salinization and solonetzation—affecting water mineralization and ion ratio. This field was further developed in Europe, Canada, India, China and other countries. A number of other countries have developed their own standards for quality of irrigation water, standards for heavy metals, pesticides, radioactive and other pollutant substances, as well as conditions for use of water with various chemical compositions.

4.1. Standardization principles and water quality criteria evaluation in irrigation

The quality of water used in irrigation is a very important factor of ecologically safety of irrigation systems; it has influence on processes of soil salinization, solonetzization and pollution, on water consumption, productivity and quality of agricultural products, and on reliability of irrigation systems. Presence of pollutants in irrigation water causes pollution of soils and groundwaters, and subssequent transportation of these substances to plants, animal and humans.

Standardization of water quality for use in irrigation involves standardization of water quality in reservoirs (irrigation source), chemical elements and other substances in soil and plants (irrigation object), and in agricultural outputs. At the same time, standardization of irrigation water quality represents an independent field of scientific research effort that has been conducted in various countries over recent decades. The problem is very complex because the processes in the “water - plant”, “water - soil - plant”, “water - soil - groundwater”, and “water - construction” systems is influenced by climate, drainage, composition, properties and capacity of soils, depth and chemical composition of groundwater, stability of agriculture towards salts and pollutants, and irrigation technology. Migration of exogenous chemicals from water to soil, plants and groundwater results in complex processes of extra-reservoir bioaccumulation and biodegradation.

In accord with this, the following principles form the basics of water quality standardization for use in irrigation:

- principle of dependence of soil richness, water consumption, productivity and quality of agriculture production on water quality, chemical composition, ion ratio, and content of polluting substances in irrigation water;
- principle of dependence of preservation, durability of materials and operational reliability of irrigation system constructions on chemical composition, properties of irrigation water, on content of suspended particles;
- principle of regional approach that takes account of specificity of climate, territory drainage, depth and chemical composition of groundwater, composition and properties of soils, irrigation technology, and cultivated agricultural phytocenosis;
- principle of risk limitation, according to which the maximum permissible concentrations of pollutant substances in water are stated, and
- principle of directional formation of chemical composition and properties for irrigation water in order to optimize the basic indexes of soil irrigation procedure and to provide micro-elements required for soil and agriculture.

In accord with the above-stated basic principles, the ecological, agronomic and technical criteria have been developed for evaluation of irrigation water quality. Ecological criteria have been proposed for evaluation of water quality with regard to environmental protection from pollution and for maintenance of public health, as well as due to close relation between irrigated cultivation and surface and underground waters—in order to evaluate water quality from the point of view of influence on surface and underground waters. The agronomic criteria are intended for evaluation of water quality with regard to maintenance of soil fertility (prevention of soil salinization, soda-formation and solonetzization processes, and disorders in microbiological regimes), for providing the desired scope (productivity, intensive development) and quality of agricultural production (full value, high quality, safety). Technical criteria are intended for evaluation of water quality with regard to preservation and durability of irrigation systems constructions, for prevention of processes of corrosion, fouling, and biological overgrowth. Along with ecological, agronomic and technical criteria, economic ones may also be used. The principles of water quality evaluation according to economic criteria are based on the acceptable risk concept. When evaluating the possibility of irrigation water having increased mineralization and undesirable composition, one should take into account the cost of water quality improvement on one hand, and, on the other, the losses arising from loss of soil fertility, productivity and product quality, and from higher investments in water, material and labor. When the water source contains toxic substances and metabolites thereof that are able to migrate through the water-nutrition chain, evaluation of its utilization in irrigation should be mainly based on ecological and agronomic criteria.

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