THE INFLUENCE OF SURFACE AND GROUNDWATER ON AGRICULTURAL PRODUCTION - REVIEW

Octavian Vasile GUIU[1], Cristina Maria MAERESCU[2], Ioana Maria BORZA[2], Radu Petru BREJEA[2], Nicu Cornel SABĂU [2#]

[1] Doctoral School of Engineering Sciences, Agriculture, University of Oradea, 1 University St., 410087, Oradea;
[2] Faculty of Environmental Protection, University of Oradea, 26 Gen Magheru St., 410087, Oradea

REVIEW

Abstract

Irrigation or "artificial rain" aims to supply the soil with additional amounts of water in a controlled manner, without those received under natural conditions, in order to ensure the stability of agricultural production at a high level. The main sources of water for irrigation in Romania are surface water (rivers, lakes) and underground water. The main physico-chemical characteristics that are taken into account when assessing the quality of water for irrigation are the following: temperature, turbidity, degree of aeration, reaction, concentration in chemical elements and in soluble salts. The quality of water for irrigation is assessed according to 3 categories of indicators: physical, chemical and sanitary. Water quality can influence not only production, but also its quality. The use of water of inadequate quality causes soil degradation, usually through salinization. Secondary salinization consists in raising the mineralized groundwater to the soil surface, the water evaporates, and the salts remain concentrated in the upper part of the soil profile.

Keywords: irrigation, surface water; groundwater, irrigation water quality, secondary salinization.
#Corresponding author:

INTRODUCTION

Irrigation or "artificial rain" aims to supply the soil with additional amounts of water in a controlled manner, without those received under natural conditions, in order to ensure the stability of agricultural production at a high level. The need to apply irrigation is determined by natural and socio-economic factors. Irrigation removes the damaging effects of droughts, corrects to a large extent the climate of a natural area and at the same time regulates the water regime of the soil ensuring the plants' water needs (Nikolaou et al., 2020)

Drought can present itself in different forms, the most well-known being atmospheric and pedological. Atmospheric drought means the time period of more than 10 days during the growing season in which no rains greater than 5 mm fall, temperatures are high, winds are very hot, and the relative humidity of the air is low (30-40%). In these conditions, there is an imbalance between root absorption and transpiration. This form of drought is also called physiological drought. Pedological drought is manifested when moisture falls below the so-called minimum moisture content, approaching the wilting coefficient. Soil drought is more harmful to plants than atmospheric drought, because plants get most of their water needs from the soil (Cenușă, 2016).

Plants need water at all stages of growth, from germination and planting to maturity. The presence of water in optimal quantities determines, together with other vegetation factors, the normal and economically profitable development of agricultural crops.

The main sources of water for irrigation in Romania are sometimes qualitatively affected by accidental pollution. The preservation of soil fertility depends on water quality, but also the level of agricultural production or the benefits that irrigation brings (Di Falco & Zoupanidou, 2016). In order to assess the quality of water, it is mandatory to periodically perform the physical-chemical analysis of water, because water quality changes over time, under the influence of various environmental and anthropogenic factors.

MATERIAL AND METHOD

The main physico - chemical characteristics that are taken into account when assessing the quality of water for irrigation are the following: temperature, turbidity, degree of aeration, reaction, concentration in chemical elements and in soluble salts.

The determination of trace toxic elements in drinking water is currently a problem of real interest due to the role of water in human metabolism and implicitly the consequences of the ingestion of these elements for human health.

RESULTS AND DISCUSSIONS

Surface water quality

Surface water and groundwater are the main sources of raw water used for potable water. The good quality of these sources is important for providing drinking water suitable for human consumption. Discharges of sewage treatment plant effluents, discharges of untreated wastewater or with different levels of impurity from industrial and mining activities, leachates due to the use of fertilizers in agriculture, atmospheric deposits can significantly affect water resources, both surface and underground. Consequently, various pollutants can be detected in the water such as: metallic elements, toxic organic compounds, pesticides, pharmaceuticals and various other organic micropollutants, together with pathogenic microorganisms, which result in the degradation of water quality (Vasile, 2012).

The availability of fresh water is essential for human well-being. Water is one of the most demanded of all urban and rural amenities and is irreplaceable for human actions. Due to their availability and accessibility, rivers and lakes were the most used source of surface water. This circumstance has led to the rapid development of most human progress near the banks of rivers (Loucks & van Beek, 2017). Water is an irreplaceable asset, and the benefits to humanity of legitimately managing this asset, as well as the dire penalties of mismanaging it, are very notable (Tasneem Abbasi, 2012).

Moreover, water is found in nature as surface and underground water in various structures and sources which are: springs, lakes, streams, rivers, oceans and seas, boreholes, wells, and so on. River water has various uses, including transportation, hydroelectric power generation, and various domestic, industrial, and commercial practices. Contaminated water from these sources significantly damages rivers, making the water unfit for use and causing waterborne diseases (Abowei, 2010).

Kummu et al., 2016 found in their study a nearly sixteen-fold increase in population under water scarcity since the 1900s. By 2005, about 35% of the world's population lived in countries with moderate to high water stress (Kummu et al., 2016). This percentage will increase to around 52% by 2050 (Schlosser et al., 2014). Accelerated population growth with ineffective implementation of environmental management programs has further aggravated the problem of excessive pollution levels in developing countries.

Numerous ecological computer programs have been designed to fulfill, the need for reliable data collection for adequate river water quality monitoring using the combination of software and hardware (Recknagel & Michener, 2018).

Although the informatics paradigm has matured significantly over the years (Recknagel & Michener, 2018), an efficient WQI (Water Quality Instrument) is needed to transform the collected data into valuable RWQ (River Water Quality) classification information (Tasneem Abbasi, 2012). The WQI tool is also needed to modernize the ecological informatics framework to provide accurate information to the general population, researchers and water resource managers (Recknagel & Michener, 2018).

The role of WQI is very significant for the assessment of RWQ. It transforms the raw data of multiple WQPs (Water Quality Parameters) into single value information. Can express this information quickly and logically (Tasneem Abbasi, 2012). It helps to understand the overall RWQ status of distinct monitoring locations at a given time for different beneficial uses. Chemometric (environmental) methods (eg cluster analysis, factor analysis, discriminant analysis, regression analysis and artificial intelligence, etc.) also play a vital role in environmental studies especially for RWQ monitoring and the WQI development process. Factor analysis is widely used to explain the hidden correlation between RWQ data in the form of underlying factors (Recknagel & Michener, 2018).

The need for food production, for a growing population, in sufficient quantities and of high quality, under the conditions of current global climate change is an important challenge related to the need for rational management of irrigation water (Sabău et al., 2020).

In the case of the production of certified organic tomatoes, grown in greenhouses, it is necessary to correctly establish the water requirement administered by drip irrigation, the scheduling of waterings and the correct management of soil moisture in order to maximize production (Sabău et al., 2020).

Groundwater quality

Groundwater, the largest available global freshwater resource, plays a crucial role in human sustenance and global food security through the supply of drinking water and irrigated agriculture. Recently, many parts of the world are facing groundwater depletion and widespread pollution (Mukherjee Abhijit et al., 2020).

Climate change is expected to exacerbate these problems. We need to understand the main factors controlling groundwater availability (quantity and quality) in a changing world, where climate change and human factors (overexploitation, pollution, economics, agri-food and their socio-economic aspects and government intervention) profoundly influence availability this one.

As groundwater is a critical source of water in many areas, especially in developing countries, it is necessary to analyze the physical (hydrological), chemical (hydrogeochemical) and human (socio-economic) aspects in a comprehensive framework for to define sustainability (Aslam et al., 2018).

Aquifers are increasingly considered a valuable resource for water supply but also for industrial purposes in many countries, such as Belgium (SPW-DGO3, 2016), Switzerland (Minnig, 2017), Germany (Hellauer et al ., 2018) or Italy (Colombo, 2020), among others. Therefore, groundwater conservation and protection are key issues in water resource management.

Groundwater pollution is a serious problem, because in many aquifers, the quality of groundwater is deteriorating, and thus the identification of the factors of its deterioration is of paramount importance. In particular, it is important to determine whether chemicals of concern are indeed associated with exogenous anthropogenic pollution sources or whether they have any geogenic origin and to determine the hydrogeochemical conditions that contribute to their occurrence in groundwater. On the one hand, many aquifers are affected by several anthropogenic activities (Schirmer et al., 2013).

In urban and industrial areas, the sources of pollution are of different types such as: atmospheric deposition, urban, industrial or household waste water discharges, industrial solids or liquids, waste, petrol stations, discharges at waste dumps. As a result, a wide range of organic pollutants (volatile organic compounds) and inorganic pollutants (eg heavy metals) can enter aquifers leading to deterioration of groundwater quality (Navarro & Carbonell, 2007).

On the other hand, groundwater quality can also be impaired by geogenic inorganic contaminants. In this case, their occurrence in groundwater may be due to geochemical changes in aquifer materials (high concentrations of contaminants in the rock matrix dissolving during water-rock interactions) or related to changes that facilitate the mobilization of contaminants from groundwater. Uranium, arsenic, radon and fluorine have been found to be the most dangerous contaminants in terms of impact on human health.

Groundwater is the main source of drinking water for a large part of the population, in Romania and in the world. From the point of view of water resources, compared to other European countries, Romania is at an average level. Sabău et al., 2020, mention that the western area of Oradea overlaps with the ROCR 01 water body, which occupies part of the Crișului Repede basin and is part of the Tisa river basin, and at the same time monitoring the quality of groundwater is of particular importance , for population health and for various uses including agriculture (irrigation), especially in light of the current global climate change trend.

Aquifers can be easily compromised through improper exploitation or pollution. Subsequent interventions to remedy these situations are technically difficult and extremely expensive. Considering these particularities, there is a need for the rational exploitation of underground water resources, based on the detailed knowledge of the parameters that characterize them and the application of an effective system for their management and protection. (Cristea, 2002)

In order to achieve the degree of knowledge necessary for rational and efficient use of groundwater, in most cases complex and long-term investigations are required. Research must be based on a good knowledge of the geological structure and geomorphology of the study area. The lithological and structural peculiarities of the geological formations are the elements that decide the possibility of the existence of an accumulation of underground water and the spatial development of the reservoir in which it is stored. Apart from the geological conditions, the way the aquifers are fed and the amount of water that infiltrates depends on the geomorphological characteristics, climatic elements, the way the land is used, the presence of vegetation, etc. The characterization of an aquifer must elucidate two essential aspects, of equal importance from the user's point of view: the quantitative and the qualitative aspect (Cristea, 2002).

Water quality for irrigation

The deficit, as well as water pollution, is a global problem and constitutes a challenge to ensure a quality and sufficient supply of water for society's needs. Food production to meet basic human needs and agricultural development are crucially dependent on water resources. An important part of the world's food production is achieved under conditions of agricultural systems based on irrigation. Of the approximately 1.5 billion hectares of agricultural land, 261 million hectares of irrigated agricultural land (approximately 20%) produced, in 2009, more than 40% of the world's staple foods (Humă, 2015).

Scientific research on natural waters shows that there are different indicators of the quality of water used in irrigation, each of which is useful but not satisfactory due to the variability of land conditions and water parameters, one problem being, for example, toxicity. The toxicity effect occurs when certain constituents from soil or water are taken up by plants, accumulating in high concentrations, which cause damage to crops (Cl^-, SO_4^{2-}, Na^+ ions, boron, etc.) or human health when consumed, such as be nitrates.

The current status of deep groundwater quality is high in fluorine, sodium and ammonium, strontium, hydrogen sulphide and iron. Nitrate pollution and microbial contamination prevail in groundwater. The most polluted remains the water of small rivers, which are used by the population for irrigation (Sandu et al., 2018).

The main sources of water for irrigation in Romania are sometimes qualitatively affected by accidental pollution. Internationally, in developed countries with irrigated agriculture, water from non-conventional sources is used to irrigate field crops (Nicolescu et al., 2011).

Hydrological studies are indispensable and serve to establish the possibilities of the sources from a quantitative and qualitative point of view, as well as to establish the capture solutions and the normal operation of the irrigation systems (especially in critical periods of low water). For irrigation, the following water sources can be used: running water (rivers, streams), natural lakes; large reservoirs, hill and lowland lakes, groundwater, waste water from urban sewage or livestock farms. The most important source in relation to the irrigated surface and the volume taken are the rivers, of which the Danube is in first place (MMDD, 2008).

Without drainage regulation works, only 10-15% of the river's stock could be used, which would be insufficient to satisfy the current and future consumption of the uses. For these reasons, a large number of reservoirs and interbasin diversions have been made.

In our country, hilly and lowland lakes can provide irrigation for 500 thousand ha, and underground sources for about 170 thousand ha. In many areas, existing resources are used to the maximum and begin to be insufficient during periods of drought. Beyond these quantitative limits, river waters have reached, in some sectors, pollution levels that impose restrictions on their use for irrigation or their use with caution, so as not to harm plant development and soil fertility. The waters of the large rivers and the Danube, with the exception of some sectors downstream from the discharge points of waste water from some industrial facilities, are of good quality. Regarding lowland lakes, it is worth noting that in some cases, and especially in summer, mineralization has high values.

Establishing the potential of water sources is carried out according to differentiated methodologies, depending on the nature of the water source: rivers, lakes or underground layers. For rivers, the primary material is provided by time records of levels and flows in hydrometric stations, over as long periods as possible (minimum 15-20 years). Statistical processing of these data results in the minimum, average and maximum flows and levels with the insurance required for sizing the works (with insurance depending on the importance class of the work, respectively the size of the surface of the irrigation system).

The management of water resources in hydrographic basins is carried out by the Romanian National Water Authority, through the related subunits. They can provide information on the characteristic flows and levels in the sections where irrigation intakes are planned, and all these institutions approve the collection and the conditions for water sampling, as well as those for the discharge of waste water into rivers. The flows and volumes of water provided for irrigation are highlighted in the water management balance sheets, which are drawn up and updated periodically (Constantin et al., 2009).

Water management from the existing reservoirs also falls to the units mentioned above, when several uses are served (flood mitigation, fish farming, irrigation, drinking water supply, leisure, hydropower), which exploit and maintain these works.

In the case of capturing water from underground sources, the capable flow rates of the wells and boreholes are established following test pumping and the water quality is determined based on samples that are taken after an interval of 24 hours from the start of pumping. In the case of springs, flow measurements are carried out over longer periods, especially in summer, which give the opportunity to know the flow regime and the available water stocks.

Irrigation water quality parameters

The salts dissolved in the irrigation water, as well as some of its properties, influence the metabolic activity of the plants and the evolution of the soils, which is why their analyzes are necessary, both before the drawing up of the project, and especially after the arrangement, that is, during the exploitation period. In some polluted waters, there may be toxic elements for cultivated plants or pathogenic agents that endanger the health of people and animals, that is, of consumers of agricultural products.

Water quality is assessed according to 3 categories of indicators: physical, chemical and hygienic-sanitary.

Physical indicators

1. The concentration in alluvium (improperly called turbidity), expressed in g/l or kg/m3, is determined by filtering water samples taken from the catchment area, followed by drying, weighing and reporting the weight of the solid material to the volume of the sample. High concentrations are characteristic of some sectors (middle and lower, in particular) of the inland rivers of our country, such as: Siretul, Buzăul, Argeșul, Oltul, etc.

During flood periods, maximum values of the alluvium load are observed on all rivers, so that the operation of irrigation systems during high water produces an intensification of the clogging processes of irrigation networks, with bad consequences on the transport capacity and pressures in the pipes. Clogging of irrigation canals involves a series of expenses, the higher the volume of alluvium deposited annually. Also, the clogging of channels produces malfunctions that, in some cases, can cause the interruption of watering programs and the failure to carry out watering at the necessary times.

The volume of deposits in the irrigation system depends, on the one hand, on the alluvial potential of the source, and, on the other hand, on the conditions of alluvium deposition in the irrigation canals and pipes. The highest clogging intensities are found in those systems where both the water in the river has a high concentration of alluvium and in the transport and distribution networks the water circulates at low speeds.

2. Irrigation water temperature This must be assessed not only in relation to the origin of the water (respectively the nature of the source) but also in relation to the soils, the irrigation method, the irrigated crops, the phase of plant development and the time of day when the water is distributed.

Temperature varies primarily with the origin of the water. Thus, the water in the rivers has a temperature close to that of the soil, therefore of the environment. Water in deep lakes, where thermal stratification occurs, with a cold lower layer and a warmer surface layer, must be taken from the upper zone. Water in underground aquifers generally has low temperatures (11-15 ºC) and requires heating, either in reservoirs or on the routes it travels to irrigation plots (when its transport is through open channels).

As a general indication, water is considered cold, during the summer and during the warmer hours of the day, if its temperature is below 15-20 ºC. According to some researchers, water is considered cold when its temperature is below 3/4 that of the soil, and for more tolerant cultures, when it is below 2/3 that of the air. Low irrigation water temperatures lead to a decrease in soil temperature, which, especially in spring, has negative consequences for vegetable crops (retarded growth, etc.). And in the other crops, suboptimal temperatures in the soil cause a general delay in plant development, and in more serious cases produce physiological disorders of growth, root absorption and metabolism, which negatively reflect on production (reductions of up to 25%).

3. The degree of aeration of the water

The content of dissolved oxygen in water has an important role for soil and plants. In one m^3 of water there are about 40-55 cm^3 of gases, of which 20 cm^3 CO_2, 8-12 cm^3 O_2 and the rest N. Waters coming from lakes with an advanced level of eutrophication are characterized by a low degree of aeration and respectively oxygen and therefore are not good for irrigation.

Chemical indicators

Water for irrigation must meet the conditions imposed by STAS 9450-88. Chemical analyzes of irrigation water take into account the following indicators:

1. Degree of mineralization or mineralization, refers to the total content of soluble salts per liter of water (in g/l or me/l). It can also be expressed by the electroconductivity of water, EC (in μS/cm), which is directly related to the degree of mineralization: C = 0.64 EC (g/l).

2. The concentrations of the main cations and anions, expressed in g/l or milliequivalents per liter; sodium, calcium, magnesium, chlorine, SO_4, HCO_3, CO_3, NO_3, etc.

3. Specific wastewater parameters such as: organic matter (expressed by CBO_5 and CCO Mn), nitrogen, phosphorus, potassium, heavy metals, etc.

In a complete analysis of the water, using the expression in me/l, the sum of the cations must be approximately equal to the sum of the anions, (differences above 5% show that the analyzes were erroneous). Usually, if K or NO_3 or both are not determined, the cation-anion balance is not appreciably influenced.

The opportunity to use a water source from a chemical point of view is analyzed according to the possible effects, shown below:

- secondary salinization of the soil, with known negative consequences (increasing osmotic pressure and reducing water availability for plants). The criterion for assessing the salinization potential is the degree of mineralization or the electroconductivity of the water;

- the alkalization and reduction of soil permeability is determined by the excess of sodium in the water compared to calcium and magnesium.

The limits of water framing with regard to all these effects and the assessment criteria are, of course, indicative. They are valid for "average" conditions, i.e. for soils with a sandy-loam to clay-loam texture, with good internal drainage, crops with relatively low tolerance to salinity and normal irrigation, without restrictions on irrigation norms. In practice, the conditions often differ from the reference conditions shown and, therefore, adaptations of these limits are required to the specific local situations, which concern the soil drainage, the irrigation method, the physical properties of the soils, the crops and their tolerance to salinity, water administration method, etc. The successful experiences of irrigating the coastal sands of North Africa with seawater with high mineralization are relevant, explained by the very good internal drainage of the soils.

The method of irrigation is also of great importance. From this point of view, it can be shown that submergence, as well as furrow irrigation, are less recommended for cases where the water has high mineralization. In contrast, drip irrigation is promising for watering with such waters, especially where cold season precipitation is sufficient to wash away soils and move them into the sub-root zone.

When assessing the quality of a water source, soil properties must be correlated with the irrigation and drainage method. Clay soils, with low infiltration capacity, cannot be irrigated with water with too much mineralization, because there is a risk of salt concentration in their profile and washing becomes difficult. The same for medium-textured soils which have shallow illuvial horizons and which virtually cancel out natural internal drainage and the possibility of leaching of salts brought in by irrigation water. These two situations (clay soils and soils with the illuvial horizon acting as an impermeable screen) can contribute to the development of secondary salinization and alkalization phenomena in some irrigated areas of the Prut river meadow and on the slopes and plateaus of the Bahlui hydrographic basin.

The salinity and boron tolerance of plants varies within certain limits, some of them admitting higher concentrations than others. Boron has reached concentrations of up to 2 mg/l in municipal wastewater in countries with high consumption of detergents, so that irrigation with such waters becomes risky, primarily for fruit plantations that show a high sensitivity to this chemical element.

Sanitary indicators

In-depth analyzes in this direction require, in particular, the wastewater used for irrigation, because they present a health risk (microbiological, toxicological or mutagenic), by polluting agricultural products and making people and animals who consume those products sick. The criterion for assessing water from a hygienic-sanitary point of view is the number of coliform germs per liter of water.

The risks of using polluted water are related to the pollution of agricultural products, but also to the pollution of groundwater that is used for drinking purposes. The first depends on several factors such as: the type of crop, the irrigation method, the harvesting method, the time between the last watering and harvesting, the methods of consumption of the agricultural products, and the second on: the texture of the soil, the stratification of the land up to the depth of the canvas water table, etc.

Hydrogeological conditions

The hydrogeological conditions, especially the depth of the water table, represent an important criterion for choosing the irrigation method. It refers to the regime of phreatic waters in particular, but also of deep aquifers, if they represent potential sources of irrigation.

The groundwater regime is characterized by: depth, level variations during the year (especially during April-October), flow direction, groundwater mineralization and chemical composition.

The variation of groundwater depth in irrigated areas is expressed using hydrogeological maps with isophreates. The depth of the water table is taken into account when calculating the water supply of plants by capillary rise of water; the closer the groundwater is to the base of the root system, the greater this intake. During the exploitation period of the irrigation systems, it is necessary to organize the monitoring of the evolution of the phreatic levels.

Groundwater mineralization influences soil salinization processes, especially where excessive irrigation causes the water table to gradually rise.

In the case of aquifers exploitable for irrigation, the studies refer to: the capable flow of boreholes or wells (determined by experimental pumping), the radius of influence, the necessary distance between wells or boreholes, water quality (especially from a thermal and chemical), etc.

CONCLUSIONS

Water quality can influence not only production, but also its quality. The use of water of inadequate quality causes soil degradation, usually through salinization.

In some crops, values between 0.25-0.5 mS/cm are preferred for electrical conductivity (EC), since, after the application of chemical fertilizers, it can increase up to 10 times (for example, 1 g of ammonium nitrate increases CE by 1.35 mS).

At their high values, under conditions of fertilization, concentrations of salts that are strongly limiting for production can be reached. Depending on the salinity tolerance of the plants, possible yield losses can be as high as 50%.

Very few vegetable growers request an analysis of the irrigation water. Knowing some chemical indicators is very important. The water used for irrigation must have the following properties:

• the content in soluble salts (chlorines, sulfates, carbonates) to be below 5 g/l;

• to have neutral reaction pH 6.5-7.2. Water with a pH of 5.5 – 6.4 and 7.3-7.6 can also be tolerated;

• the content in alluvium should be 1-3 g/l;

• the water temperature should be 20-28 °C (underground water is 12-13 °C);

• to have a good degree of aeration with 7-14 g/m^3 oxygen.

Irrational irrigation can have some negative consequences:

• unjustifiably increases expenses and thus the price of agricultural products;

• excessive and repeated wetting is unfavorable both to plants and to microbiological activity in the soil;

• large amounts of water damage the soil structure;

• the worst is that it produces secondary salinization and waterlogging of the soil.

Secondary salinization consists in raising the mineralized groundwater to the surface of the soil, the water evaporates, and the salts remain concentrated in that area. Secondary salting is also when water with a salt content of more than 5 g/l is used.

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