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IMPORTANCE OF CHEMICAL AND MICROBIOLOGICAL WATER QUALITY FOR IRRIGATION IN ORGANIC FOOD PRODUCTION

SUMMARY

The quality of water used for irrigation of organic food crops is important for maintaining and protecting the environment on which the product quality often depends. Water quality requires a careful approach because of the adverse effects that can be manifested both in the soil and in the plant products.

Intensive technical and technological development in all branches of the economy is a major cause of pollution of the environment, primarily of water. The most frequent polluter of soil (i.e. of the medium from which plants take up nutrients) is irrigation water. Plant products that are used for food production become polluted through this medium.

Water with the potential to contaminate plant products with harmful substances can arise from various sources, especially surface waters contaminated with waste industrial and communal waters, or water from agricultural farms. An analysis of some irrigation systems in Serbia reported that 25% of these systems do not meet water quality requirements. This has resulted in an increase in salt concentrations in the soil above allowable levels, precluding the pursuit of organic agriculture.

Besides the total amount and the content of certain pollutants in the form of salts, other harmful and dangerous substances found in irrigation water often come from chemicals that are used in agriculture as pesticides and nutrients, and from the waste waters, or wastes deposited in the watercourses. In addition, certain microorganisms can also be responsible for the presence of toxic components.

Water quality and its hygienic safety, especially in vegetable irrigation, are extremely important due to the increased demand for healthy and safe food. Irrigation water can transfer microorganisms to plant products, leading to outbreaks of diseases such as salmonella, *Escherichia coli* 0157:H7, *Cryptosporidium parvum* and others. Water from surface sources is more prone to contamination than is water from underground sources.

Key words: Irrigation, water quality, environment, organic production, microbiological safety

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INTRODUCTION

Recent studies dealing with soil conservation subjects have discussed (Brandt and Thornes, 1996; Geeson et al., 2002; Hill et al., 2008; Hooke, 2006; Kosmas et al., 1997; Le Houérou, 1989, Spalević, 2011), and sometimes questioned (Nyssen et al., 2012, Butzer, 2005; Grove and Rackham, 2001, Spalević et al., 2012), the magnitude of land degradation and desertification in our Region, the human responses, and the linkages with land use and cover (LUC) changes, where water is one of the causes of positive but also negative effects on the land and environment. Irrigation is an important human activity for the growth of vegetation, and vegetation plays an important role in improving soil quality, reducing runoff and preventing soil loss (Zha et al. 1992; Tompson et al. 2005, Spalević, 2011); that is, vegetation increases soil infiltration capacity and reduces soil erosion (Zigler and Giambelluca 1998; Bochet et al. 1999). Effective soil and water conservation programmes require the concentration of resources in limited areas (Vrieling et. al, 2006). Organic Agriculture increases the resilience of soils to both water stress and nutrient loss. It contributes to combating desertification by preventing soil erosion and land degradation as well as by helping rehabilitate degraded land.

Water quality has a great significance in organic food production. Sources of good quality water for irrigation are mostly limited, and farmers are increasingly directed to use weakly or even strongly mineralized water, waste water or water from livestock farms, urban areas, or manufacturing plants. Use of this water for irrigation not only can contaminate the soil and increase its salinity, but the plants and their products, which are used for human and animal nutrition, can also be rendered harmful and dangerous to human health.

Organic food production is characterized by certain peculiarities in the agricultural production and usually takes place in limited areas and with certain plant species, which are primarily consumed fresh. Due to changing and instable weather conditions, irrigation is often used as a supplementary irrigation in the Balkan region, and it is a regular measure for vegetables. By knowing the production conditions and respecting the positive effects of irrigation, we should strive for a rational watering regime, adjusted for specific types or groups of vegetables (Bošnjak, 2003).

Irrigation in organic food production is characterized by certain speciality in relation to irrigation in classical plant breeding. Organic production primarily includes plant species that are consumed as fresh or preserved products. These plants produce a huge green mass with a very high percentage of water, and a very well developed ground mass with a relatively poorly developed root system. For these reasons, they have a great need for water.

Irrigation in organic agriculture plays a vital role in maintaining and protecting the environment on which the product quality often depends. It requires a careful approach because of the adverse effects that can be manifested both in the soil and in the plants. Grul (1985) emphasizes that, in the implementation of irrigation, we should strive “not to use the soil as if we are the last generation, that soil and water must be treated as natural wealth, as our capital, and not just as our profit."

Besides its effects on the soil, water used for irrigation has a great effect on cultivated plants. According to some authors (Ayers and Westcot, 1985), when water of inappropriate quality is used for irrigation, we can expect to see a decrease in yield and deterioration in product quality. Recently, the risk of harmful consequences of irrigation with contaminated water in the food production has become more evident because of the general trend of worsening of the water quality for irrigation, the irrigation of larger areas, and the use of waste waters in irrigation (Kastori, 1995).

RESULTS AND DISCUSSION

Specific of irrigation in organic food production

Irrigation in organic food production provides constantly green fields as two or three crops can be produced per year and it provides high yields and stable production. Irrigation is important not only for its effects on plant growth and development, but because it also maintains the physical, chemical and microbiological characteristics of the soil. The preservation of soil properties is the basis on which all measures of organic production are based. Most of the products in organic food production are susceptible to pollution, to a certain extent, because a certain amount of harmful substances is always present in the soil, water and air. Water is a frequent pollutant of the soil, from which the plants obtain dissolved nutrients.

Most of the crops in organic food production are cultivated purely by irrigation, because only this type of production can generate high yields of the appropriate quality. According to the cultivation technology, these crops differ from some others, but the basic irrigation principles are similar and common. The majority of the crops grown for organic food production, such as vegetable plants, require higher levels of soil moisture compared to field crops (Dragović, 2012), because of their weakly developed root systems in relation to the above-ground parts of the plant, which transpire a large amount of water. In addition, vegetable plants contain a high percentage of water in their tissues. Most of the vegetable crops have weakly developed root systems with the weak suction power, so they can use water from the soil only when it is sufficiently moist (Dragović, 2008, Dragović et. al, 2004). The root is usually developed in the surface layer of the soil; this is especially the case in hotbed production, where the water reserves are limited and unstable. In most vegetable plants, the mass of the surface part of the plant is 10 to 26 times larger than the mass of the root system (Bošnjak, 1999).

Different plants, but especially vegetable crops, have different irrigation requirements (Dragović et al. 2005). Plants with the shallow roots, such as lettuce, peppers, celery, etc., require frequent low volume watering. Plants with deep root systems use water from a larger volume of the soil profile and therefore do not require frequent watering (Dragović et al. 2006).

Problems of contamination by microorganisms in plants and products used in human nutrition are mainly found in crops irrigated by sprinklers. With drip irrigation systems, water does not come in contact with plants or their fruits;

therefore, there is a small chance for contamination of food products. With mini-sprinklers, which burst water under the plants, the possibility of contamination of fruits is also low.

Selection of water for irrigation in organic food production should be carefully assessed. If the water quality does not meet certain standards, then a drip irrigation system and equipment should be installed so that water does not moisten the plants. In cases where contaminated water is used for irrigation, filtration is necessary (Dragović et. al, 2007). According to Verhallen and Roddy (2003), the relative depth of the root system of plants is different, especially for vegetable plants (Table 1).

The irrigation time, as well as the quantity of water that should be added, is often established according to a cycle. At that, rainfall should be taken into consideration, so that irrigation time is delayed for a day for every 5-6 mm of rain, and if the rainfalls are over 20-30 mm, the whole cycle will be shifted. Many vegetable plants have certain phases of development in which water stress significantly reduces the yield and the quality (Lazić, 1998).

Table 1. Vegetable plants classification according to the depth of the root system

With shallow root (to 30 cm)	With medium depth (30-60 cm of depth)	With deep root (deeper than 60 cm)
Celery Salad Onion Potato Radish	Broccoli Beans Cabbage Carrot Cauliflower Cucumbers Pepper Tomato Zucchini	Asparagus Pumpkin Sweet corn Watermelon Winter spinach

Irrigation has a special significance in periods critical for water, which are listed in Table 2.

Table 2. Critical periods of some vegetable plants for water

Critical period	**Plant**
Flowering and fruit formation	Beans
Formation and growth of heads	Broccoli, Cabbage, Cauliflower
Panicle stage, fertilization, the growth of cobs	Sweet corn
Flowering and formation and growth of fruits	Cucumbers, Zucchini, Melons
Formation and growth of bulbs	Onion
Flowering and formation and growth of fruits	Eggplant, Pepper, Tomato

Crops cultivated at high plant densities are mostly irrigated by sprinkler systems (Šoškić et. al., 2001). However, with certain types of plants, especially those susceptible to certain diseases, irrigation by sprinklers is not appropriate because moistening of the surface parts of the plant creates conditions for the occurrence of certain diseases, or the crop can be contaminated if the water is hygienically unsafe. Therefore, crops such as vegetables should be irrigated by a drip system or by ridges.

Figure 1. Sprinkler irrigation system – centre pivot

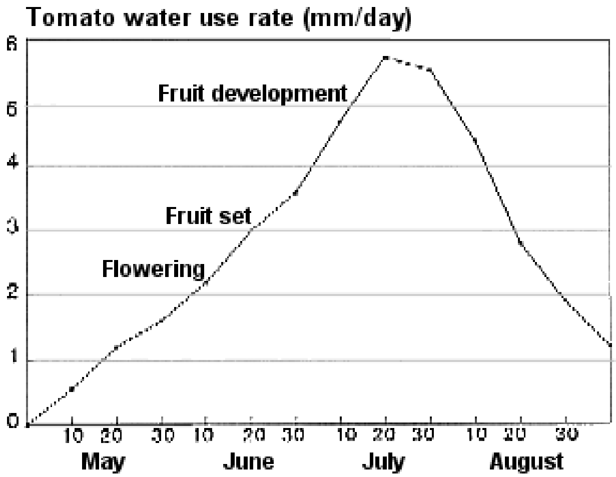

Figure 2. The dynamics of water absorption by tomato plants (mm/day), (Tan, C.S., 1980)

Many types of crops are sensitive to Water regime (Šoškić and Spalević, 2001; Šoškić and Spalević, 2001a), which should be taken into consideration during the system construction and when planning the sowing structure. Water quality is of a great importance for vegetable crops and for production for food in the green state because irrigation with water that contains harmful and dangerous substances higher than a maximum limit can endanger the quality and the health safety of organic food products (Dragović, 2005).

Figure 3. Drip irrigation of tomato and pepper

Irrigation water quality from the aspect of chemical safety

Production of organic food is closely connected to exploitation of natural resources; i.e. the quality of soil, water and air. The close connection between organic agriculture and the broader environment has been recognized and implemented into regulations of the Republic of Serbia, as in other countries. Modern principles of production of safe food focus not only on obtaining high food quality, but also emphasise preservation of the environment and sustainable exploitation of natural resources.

Water quality has a special importance in the irrigation of organic food crops. Water for irrigation comes from a broad range of sources, including rivers, streams, natural and artificial accumulations (lakes) and underground aquifers, and increasingly more often from wastewaters, but the water quality is significantly different among these different sources. In addition to the total amount and content of certain pollutants, water quality is also affected by temperature, the suspension of solid substances and the chemical substances present in wastewaters, including pesticides, as well as by the presence of certain microorganisms.

Wastewater is often discharged into the surface water systems, which significantly deteriorates the quality of these sources. Dragović et al. (1996/a) point out that in addition to the total quantity and content of certain types of salts, the water quality is influenced by dangerous and harmful substances that exist in water used for irrigation, and most of these substances are chemicals used in agriculture or substances from wastewater or wastes that are discharged into the water currents. All macro elements and microelements that are within used in the nutrition of plants are harmful to plants at high concentrations and pose a threat to the human and animal nutrition.

In addition to contamination of irrigation water, soil contamination with harmful and dangerous substances can occur, as can increases in concentrations of salt due to mineralized ground water; from rainfall, where particles from the air are transferred to the land; or from flooding or leakage of water from rivers that are contaminated. The analysis of the soil profile at 0-125 cm depths in 14 irrigation systems showed that seven of these systems had increases in dissolved salts from 0.11 to 0.28% (Dragović et al 2007). High salinity soil caused by irrigation water reduces the ability of plants to use water and nutrients normally; consequently, the plants lag behind in growth, and show reduced yield and deteriorated product quality. The factors that influence irrigation water quality are not only the total salt concentration but also include the types of individual salts present and the presence of chemical substances originating from sewage, pesticides and others. Different sources of water for irrigation have different quality. The best quality is usually current water because it has small concentrations of salt, but it may have a large amount of physical contamination in the form of sand, mud and other impurities.

Technological development and growth of industrial production in recent decades have increased the problem of water quality. Natural sources of water and watercourses generally have become the recipients of huge amounts of wastewater. In addition, most watercourses are exposed to many new sources of pollution. The amounts of good quality water in nature are diminishing, and this trend is continuously worsening.

The use of poor quality water for irrigation can cause the following problems:

–Soil salinisation and alkalinisation,
–Deterioration of the physical properties of the soil,
–Toxicity to plants and contamination of their products,
–Combined influences of two or more of these problems.

The problems of irrigation water quality are often complex. Water polluted by a combination of toxic and harmful substances has a more severe impact on plant productivity and the quality of the harvested products than when they are contaminated by individual substances. If more problems cause poor water quality, it is difficult to recognize them and implement measures for their removal. In addition, all applied measures need to be cost-effective.

The suitability of water for irrigation is characterized not only by the total content and concentration of salt, but by the concentrations of specific types of salts. Salts in water for irrigation are present mostly in relatively small quantities (Table 3).

The most common elements present in water are calcium, magnesium, sodium and potassium, and they form salts with bicarbonate, sulphate and chloride. Other ingredients, such as nitrates, carbonates and microelements, may also be released into the water in some cases and can also affect water quality, and thus, the quality of plant products. Nitrate can be present in the water in local areas at significant concentrations, as is the case in some channels of the hydro system of the Danube-Tisa-Danube Canal in the province of Vojvodina, the Republic of Serbia (Dragović et al 2008).

Table 3. Types of salts that are commonly found in the water for irrigation

Chemical name	Chemical symbol	Approximate concentration in water
Sodium chloride	$NaCl$	Medium to high
Sodium sulphate	Na_2SO_4	Medium to high
Calcium chloride	$CaCl_2$	Medium
Calcium sulphate	$CaSO_4 *2H_2O$	Medium to low
Magnesium chloride	$MgCl_2$	Medium
Magnesium sulphate	$MgSO_4$	Medium to low
Potassium chloride	KCl	Medium to low
Potassium sulphate	K_2SO_4	Low
Sodium bicarbonate	$NaHCO_3$	Low
Calcium carbonate	$CaCO_3$	Low
Sodium carbonate	Na_2CO_3	Traces or no traces
Boric acid	BO_3^{---}	Traces or no traces
Nitrates	NO_3^-	Low or no traces

When a salt builds up in the soil to toxic amounts, it primarily affects the growth and development of plants. When using irrigation water that transfers large amounts of salt and other chemical substances to the land, pure water evaporates from the soil, while the salt and other chemicals remain on the surface of the soil and gradually build up. Longernecker and Lyerly (1974) determined how much salt can accumulate in the soil, when irrigating with water containing different concentrations of salt, if no conditions exist for their relocation in the deeper layers (Table 4).

Table 4 shows how much salt can be accumulated in the soil over six years, when irrigated with water of different concentrations of salt, if the annual norm of irrigation is 300 mm, or 3000 m^3 . If 3,000 m^3 of water contains 1 ton of salt, in most cases the water is of poor quality. Intensive irrigation at about 3,000 m^3/ha (300 mm) for three or more years can result in the accumulation of enough salt in the soil to cause harm to salt-sensitive plants. Four years of accumulation of salt will not only adversely affect the majority of plants but will also cause salinisation of the land.

To illustrate, Belic et al (1996) stated that when the quantity of dissolved salts in the irrigation water is 1.000 mg / l, and the irrigation norm is 200 mm, then 2,000 kg of harmful salts will be added to the field per year. These lands are not suitable for organic agriculture and healthy food production.

Table 4. The amount of salt present in soils irrigated with 3000 m³ of water containing different concentrations of salt.

Salt, in tons, in 3000 m³ of irrigation water	Tons of salt added by irrigation of land with 3000 m³ of water					
	1. year	2. year	3. year	4. year	5. year	6. year
0.5	0.5	1	1,5	2	2,5	3
1	1	2	3	4	5	6
2	2	4	6	8	10	12
4	4	8	12	16	20	24
6	6	12	18	24	30	36

Years of testing the influence of water quality on salinity of the land and deterioration of the quality of plant products have allowed establishment of limit values that have different effects on yield and quality of plants and the accumulation of harmful and dangerous substances in the soil (Ayers and Westcot, 1985) (Table 5). The displayed value can be successfully used for assessment of irrigation water quality for organic agriculture. Although different sources of water are used for irrigation, the types of salts are similar, but their presence and concentrations can significantly differ. For this reason, strict water quality control is necessary, especially when it comes to irrigation for organic food production.

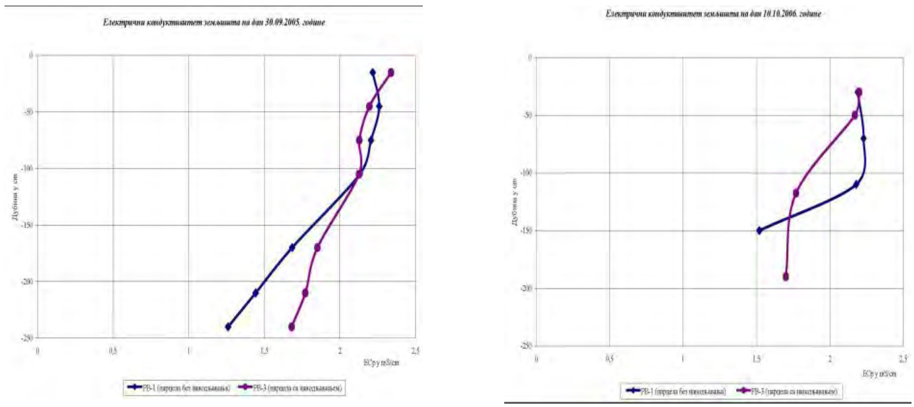

Figure 4. Electrical conductivity in the heavy soil after using saline water for irrigation. (Dragović et al 2007)

Use of irrigation water with quality values lower than the limits are listed in the column "unrestricted" (Table 5), as these do not generally cause problems in the soil or deteriorate the quality of plants that are irrigated. In the column entitled "Low to medium restriction” attention should be paid to the choice of plants that will be grown and on measures that should be used to achieve the full potential of yield and acceptable quality. On the other hand, if the water has equal or greater values than those specified in the "severe restriction" column, it cannot be used for irrigation in the production of organic food.

Table 5. Guide for irrigation water quality

Potential problems in irrigation	Unit	The level of water use restrictions		
		unrestricted	small to medium limit	Sever restriction
Salinity (impact on water accessibility to plants)[2]				
Electroconductivity – ECw	$dS \cdot m^{-1}$	< 0,7	0,7 – 3,0	> 3,0
– URS	mg/l	< 450	450 – 2.000	> 2.000
Infiltration (estimated on the basis of ECW and SAR together)[3]				
SAR = 0 – 3 i ECw		> 0,7	0,7 – 0,2	< 0,2
= 3 – 6		> 1,2	1,2 – 0,3	< 0,3
= 6 – 12		> 1,9	1,9 – 0,5	< 0,5
= 12 – 20		> 2,9	2,9 – 1,3	< 1,3
= 20 – 40		> 5,0	5,0 – 2,9	< 2,9
Toxic ions (impact on sensitive plant)				
Sodium (Na)[4]	SAR			
Surface irrigation	mmol/l	< 3	3 – 9	> 9
Sprinkler Irrigation	mmol/l	< 3	> 3	
Chlorides (Cl)[4]				
Surface irrigation	mmol/l	< 4	4 – 10	> 10
Sprinkler Irrigation	mmol/l	< 3	> 3	
Bohrium (B)	mg/l	< 0,7	0,7 – 3,0	> 3,0
Various influence to sensitive plants				
Nitrates (NO_3 – N)[5]	mg/l	< 5	5 – 30	> 30
Bicarbonates (HCO_3)	mmol/l	< 1,5	1,5 – 8,5	> 8,5
pH	In the range of 6,5 – 8,4			

[1] Adapted from: University of California Committee of Consultants

[2] ECw – electrical conductivity in deciSiemens per meter at 25°C (dS/m), or milimhos per centimetre (memo/cm). Both are in use and they present salinity of water. URS – total dissolved salts, expressed in milligrams per litre (mg/l)

[3] SAR – Sodium adsorption ratio. Infiltration increases as salt concentration increases for particular SAR. Assessment of problem of infiltration by SAR modifies with ECW.

[4] In surface irrigation, most woody plants are sensitive to sodium and chloride. Most annual plants are sensitive to irrigation and at low relative humidity of air (<30%). Sodium and chloride can be taken up through the leaves of sensitive plants.[5] NO_3– N – means nitrate nitrogen. When using wastewater, NH4-N and organic N should be included.

Table 6. The maximum allowable concentrations of some elements in irrigation water

Elements	Allowable Max Concentration (mg/l)	Note
Al Aluminium	5,0	It can cause a decrease in productivity of acid soils (pH <5,5), but in soils with pH>7 ions are deposited and eliminate any toxicity.
As Arsenic	0,10	Toxic to plants in the range of 12 mg / l for Sudan grass To 0.05 mg / l for rice.
Be Beryllium	0,10	Toxic to plants in the range of 0.5 mg / l for kale to 0.05 mg / l for the beans.
Cd Cadmium	0,01	Toxic for many plant species in the concentration. 0.1 mf / l in nutrition solution. Potentially risk of accumulation in soil.
Co Cobalt	0,05	Toxic to tomato in conc.0. 1 mg /l in nutrition solution. In neutral and alkaline soils is less active
Cr Chromium	0,10	It is not known as a biological growth element Limit it is determined on the basis of toxicity.
Cu Copper	0,20	Toxic for many species in the concentration from 0.1 to 1.0 mg / l in the nutrition solution
F – Fluorine	1,00	In neutral and alkaline soils no active participation
Fe Iron	5,00	It is not toxic to plants in aeris soils, it causes acidification of land and loss in present of phosphorus and molybdenum.
Li Lithium	2,50	Many plants tolerate it in the soil. Toxic for citrus At concentrations> 0. 57 mg / l. According to activity, it is similar to Bo.
Mn Manganese	0,20	Toxic to plants that are usually present in acid soils, in the concentrations of several tens to several mg / l.
Mo Molybdenum	0,01	It is not toxic to plants at normal conc. in soil and water It can be toxic to cattle, if the silage is grown on land. With high concentrations of present molybdenum.
Ni Nickel	0,20	Toxic for many plant species in conc. at 0.5 to 1.0 mg / l, toxicity reduces in neutral and alkali environment.
Pb –Lead	5,00	It can inhibit the growth of plant cells at high concentrations.
Se Selenium	0,02	Toxic for plants at low concentrations of 0. 025 mg / l. Toxic for cattle if the silage is produced on the land With a high concentration. An essential element in a very low concentration.
Zn Zinc	2,0	Toxic for many plants in concentration of wide range. Toxicity was reduced at pH> 6 in organic soil of fine texture.

Another problem can be caused by toxicity of microelements that are present in the irrigation water, usually in traces (Table 6). The concentration of these elements is usually low (a few mg / l), and in most cases is only traces (microgram per litre). Harmful and toxic elements mainly come from wastewater or wastes; therefore, it is necessary to protect rivers from absorbing harmful and dangerous substances, especially those rivers intended for irrigation of plants for organic food production. Some of these elements, such as Fe, Mn, Zn and Mo, are biogenic and are essential in plant nutrition in very small concentrations. However, increased concentrations are toxic to plants and adversely affect the growth, development and yield, and especially the quality of plant products.

Irrigation water quality from the aspect of microbiological safety

Water quality and its hygienic safety in irrigation of organic food production are extremely important due to the increased demand for healthy, safe food. Water can transfer disease-causing microorganisms to the plant products, such as: salmonella, *Escherichia coli* 0157:H7, *Cryptosporidium parvum* and others.

Irrigation with waste (i.e. contaminated water) where people use green products for consumption presents a risk of contamination of the surface green parts of the plants, and therefore the consumption of these products may cause a disease in people. Plants that produce a large green mass with a very high percentage of water have relatively weakly developed root systems; thus, they require a lot of water and frequent watering to sustain high levels of soil moisture in the vegetative period. Water from surface sources is more prone to be contaminated compared to water from the underground sources. Surface waters can be microbiologically contaminated from the following sources:

- Faeces,
- Erosion of organic wastes by water due to the abundant rainfall, as a result of complex effects of a whole group of factors (Ćirić, 1975; Zaslavskÿ, 1979, Spalević et Al., 2000, Spalević et Al., 2001, Spalević, 2011). The major drivers for this erosion are intense rainfall, topography, the percentage and type of vegetation cover, and inappropriate farming practices (Vukelic-Shutoska et al., 2011).

Water quality in accumulating water depends on the water quality that flows into it and the way it is protected from polluted waters. We should strive to provide a good quality for water that flows into an accumulation. According to Cassel (2004), variations in irrigation water quality depend on the water source, as follows:

- Rivers and streams	High quality variability
- Accumulations	High quality variability
- Lakes	High quality variability
- Accumulations transferred by the underground waters	Medium quality variability
- Underground water-wells	Low quality variability

Water pollution in accumulations is especially emphasized in the period of intensive rainfalls, when a large amount of organic and mineral substances are introduced and settled down. These sediments can have very high levels of bacteria, because bacteria are strongly associated with the organic particles.

Polluted (contaminated) water comes in direct contact with plants, creating a risk that these pathogens can be directly transferred to the plants that are used for human consumption in the fresh state. Therefore, irrigation water analysis for pathogens is very important and should be mandatory in organic food production especially when it is used for consumption in the fresh state.

The characteristics of plants and their products that are used in human nutrition are important when irrigation is performed with contaminated water. Fruits and vegetables, which have large leaf or fruit areas, and especially when they have rough surfaces, such as with salad greens, will retain the wet surface and have the best conditions for contamination of pathogens. Fruits and vegetables that are consumed fresh, unwashed and unpeeled therefore represent the greatest risk of absorption of pathogens into the human body. Cooking or processing of products reduces the potential for pathogens to survive.

The risk of contamination with pathogens is greater when the plant fruits come into contact with contaminated water just before harvest, or in the period after harvest, during the collection and processing. Pathogens are more likely to survive on the fruits when the time between contamination and consumption is short.

The risk of microbiological pollution of food by irrigation water depends on:

- The number and the type of pathogens present in the water,
- Water source,
- The type of irrigation,
- The time of irrigation in relation to the harvest period,
- Plant characteristics,
- The immunity of the individuals that consume the plant products.

For some pathogens, such as *Escherichia coli* 0157:H7, consumption of food harbouring only a few bacteria (less than 10) can be sufficient to cause the disease. The risk of taking in one or more pathogens depends on their ability to survive on the plant product.

According to the criteria in Canada, the irrigation water quality, from the aspect of pathogen presence, is established on the basis of the *Escherichia coli* 0157:H7 bacteria number, which indicates the presence of bacteria in the water. The maximum level for the pollution of water that is used for irrigation is 100 *E. coli* bacteria in 100 ml of water, or the total number of all bacteria is 1000 bacteria in 100 ml of water (Jones, 2005). For irrigation water quality tests in relation to the pathogens, it is necessary to establish the bacteria number, then the number of faecal bacteria and the *Escherichia coli* bacteria.

Contamination problems in plant products are notable with rainfall irrigation. With the drip irrigation systems, the water is not in contact with the plants and their fruits; hence, there is a lesser possibility for contamination of the products used in consumption. The use of mini sprinklers, which sprinkle water under the plants, also lessen the possibility for product contamination.

Figure 5. Drip irrigation of tomato

Figure 6. Irrigation: micro sprinkler

Figure 7. Sprinkler irrigation by a big gun

Reduction of the risk of plant product contamination by irrigation can be realized in several ways:

- By choosing the irrigation method and technique (using a drip system instead of the rainfall system),

- By choosing the water source,
- By cleaning the water using the reliable filters.

Waste waters from some production processes in agriculture or water from farms can be used for irrigation in the production of tuberous root vegetables, but not for crops whose green parts are used in human consumption. However, their usage must be monitored with detailed and constant examination of solute chemical substances and the effect on the changes in the soil and the plant production quality. Belic et al. (1996) emphasized that the basic criterion for the choice of water quality can be historical examination of presumptions about the adverse effects of the used waters for the soil and the plant. The categorization of irrigation water should be done on the basis of contemporary qualifications, such as the modified FAO classification.

Sources of water for irrigation and their protection from contamination

Water for irrigation comes mainly from surface or groundwater. Surface waters include rivers, lakes, reservoirs, streams, canals and others, and groundwater comes from underground. In the Republic of Serbia, for the major irrigation areas, irrigation water is mainly surface water: rivers, reservoirs, canals and other hydro systems. Irrigation of small areas is mainly via underground water from wells.

The contamination level of surface water is different, because the water sources are subject to regular or occasional passage of waste and polluted water. Rivers and streams have unpredictable quality because the upstream constantly changes the level of contamination. Lakes and reservoirs have better water quality; however, they may be contaminated by the inflow from contaminated rivers or streams. For this reason, the quality of water in reservoirs depends on the quality of water that flows into them and the ways of protection against polluted water.

Pollution of water in reservoirs is especially prevalent during intense rainfall, which deposits a huge amount of organic and mineral substances. The sediments may have high levels of bacteria, because bacteria are strongly associated with organic particles.

Water from wells or wastewater settlements that were previously purified has reliable irrigation quality. Groundwater is purified as it passes through the layers of soil to the wells, as the soil acts as a natural filter. However, there is always a potential opportunity for contamination, so that water users must be careful during the construction of irrigation systems and in the use and purification of water.

Protection of water resources from contamination contributes to good quality water for irrigation. Establishing areas protected from pollution around the water intake reservoirs and groundwater helps to prevent water pollution. This includes protection against access to the water intake areas by wild and domestic animals. Septic tanks and other water pollutants should be located far enough away from water resources to ensure that water from these contaminant sources does not leak into the irrigation system.

A reliable way to prevent contamination of plant products is a regular quality control testing of water used for irrigation. The frequency of water analysis depends on the risk factors for water contamination and products that are moistened during irrigation. It also depends on the water source and its quality. Water that has a higher risk of contamination requires more frequent analysis. More frequent water quality analyses are recommended with irrigation for organic food production than for conventional crops. Irrigation analysis is recommended at the beginning and end of the season when using ground water, and at least quarterly during the irrigation season when using surface water. For plant products that are used fresh, such as salad greens and tomatoes, etc., monthly analysis is recommended.

Analysis of irrigation water quality should be done from the aspect of chemical substances: i.e. the total amount of salt and the content of specific cations and anions, macro elements and pesticides residues, among others. For pathogens, determination of the total number of bacteria is necessary, followed by the number of faecal bacteria and then grouping of bacteria into *Escherichia coli* and other microorganisms that contaminate the water.

CONCLUSION

Irrigation water quality is one of the main concerns in organic food production. The most common source of pollutants of the soil and the environment in which food plants grow is the water used for irrigation.

Plants that are grown for organic food production require a higher level of soil moisture compared with the farm crops in conventional production, because of their weakly developed root systems in relation to the surface part of the plant, which transpires a large quantity of water.

In the irrigation of organic food crops, water quality bears a special importance, since water from different sources, including waste waters, are frequently used for irrigation.

Necessary macro elements, as well as biogenic micro elements, when present in increased concentrations in the water for irrigation, may become toxic to plants and may be present in toxic amounts in plant products meant for consumption by people and animals.

Waste waters from some production processes in agriculture or from farms can be used for irrigation for tuberous roots plant production, but not for crops where the green parts are used for human consumption.

Irrigation water can transfer disease-causing microorganisms to plant products, such as salmonella, *Escherichia coli* 0157:H7, *Cryptosporidium parvum* and others.

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ZNAČAJ HEMIJSKOG I MIKROBIOLOŠKOG KVALITETA VODE ZA NAVODNJAVANJE KOD PROIZVODNJE ORGANSKE HRANE

SAŽETAK

Kvalitet vode za navodnjavanje kod organske proizvodnje hrane igra veoma važnu ulogu, a od kvaliteta vode najčešće zavisi i kvalitet proizvoda. Kontrola kvaliteta vode zahtijeva pažljiv pristup zbog negativnih efekata koji mogu da se manifestuju i na zemljištu i na biljnim proizvodima.

Intenzivan tehničko–tehnološki razvoj u svim granama privrede je glavni uzrok zagađenja životne sredine, a prije svega vode. Najčešći zagađivač zemljišta, kao medijuma iz kojeg biljke uzimaju hranljive materije je voda za navodnjavanje, koja ukoliko nije odgovarajućeg kvaliteta, utiče da biljni proizvodi, koji koriste ovu vodu za proizvodnju hrane, postaju zagađeni.

Voda koja može zagaditi biljne proizvode štetnim materijama može doći iz različitih izvora, posebno od površinskih voda kontaminiranih od otpadnih industrijskih i komunalnih voda ili sa poljoprivrednih gazdinstava.

Analize kvaliteta vode u nekim sistemima za navodnjavanje u Srbiji su utvrdile da u 25 odsto sistema kvalitet vode za navodnjavanje ne zadovoljava potrebne standarde, što je uticalo na povećanje koncentracije soli u zemljištu iznad dozvoljenog nivoa.

Pored ukupne količine i sadržaja određenih zagađujućih materija iz soli, štetne i opasne materije u vodi za navodnjavanje često dolaze od hemikalija koje se koriste u poljoprivredi, kao što su pesticidi i hraniva, zatim od otpadnih voda, ili otpada deponovanog u vodotocima, kao i od prisustva određenih mikroorganizama prisutnih u vodi za navodnjavanje.

Kvalitet vode i njena higijenska ispravnost izuzetno su važni kod navodnjavanja povrća zbog povećane tražnje za zdravstveno bezbjednom hranom, a voda može prenijeti mikroorganizme na biljne proizvode, koji izazivaju bolesti kod ljudi, kao što su: Salmonella i Escherichia coli 0157:H7, Cryptosporidium parvum i drugi. Voda iz površinskih izvora je više sklona da bude zagađena u odnosu na vodu iz podzemnih izvora.

Ključne riječi: navodnjavanje, kvalitet vode, životna sredina, organska proizvodnja, mikrobiološka bezbijednost