Wastewater reuse in agriculture and social acceptance: case study region of Istria County

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Wastewater reuse in agriculture and social acceptance: case study region of Istria County

MASTER THESIS

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Diplomskog rada studenta **Ivan Puž**, naslova

WASTEWATER REUSE IN AGRICULTURE AND SOCIAL ACCEPTANCE: CASE STUDY REGION OF ISTRIA COUNTY

Istarska županija suočava se s ograničenim prirodnim vodenim resursima, što izaziva pritisak na korištenje vode, osobito tijekom ljetnih mjeseci kada potražnja raste zbog poljoprivrede i turizma. Kako bi se riješio ovaj problem, istražena je moguća primjena tretiranih otpadnih voda u poljoprivredi radi očuvanja ograničenih vodenih resursa. Cilj ovog diplomskog rada bio je provesti istraživanje gospodarenja otpadnim vodama i razmotriti njihovu održivu primjenu u poljoprivredi Istarske županije. Provedena anketa među različitim dionicima, uključujući poljoprivrednike, znanstveno-nastavno osoblje, turistički sektor i javni sektor, poslano je 120 individualnih email adresa te prikupila je 36 valjanih odgovora. Rezultati istraživanja ukazuju na visoku stručnu spremu i prisutnost vlastitih poljoprivrednih gospodarstava među većinom ispitanika. Iako su svjesni problema s nedostatkom vode tijekom ljeta i razumiju osnovni koncept ponovne uporabe otpadnih voda, većina ispitanika nema dovoljno informacija o kvaliteti i mogućnostima korištenja tih voda za navodnjavanje u poljoprivredi. Zaključak naglašava potrebu za edukacijom dionika kako bi se podržala održiva primjena tretiranih otpadnih voda u poljoprivredi Istarske županije.

Ključne riječi: ponovna uporaba voda, poljoprivreda, upravljanje resursima, klimatske promjene, suša

Summary

Of the master’s thesis – student **Ivan Puž,** entitled

Wastewater reuse in agriculture and social acceptance: case study region of Istria County

The Istria County is facing limitations in its natural water resources, resulting in increased pressure on water usage, particularly during the summer months when demand rises due to agriculture and tourism. To address this issue, the potential application of treated wastewater in agriculture to conserve limited water resources was investigated. The objective of this master's thesis was to conduct research on wastewater management and explore its sustainable utilization in Istria County's agriculture. A survey was conducted among various stakeholders, including farmers, academic staff, the tourism sector, and the public sector, the survey was sent on 120 personal emails yielding 36 valid responses. The research results indicate a high level of education and the presence of individual agricultural holdings among the majority of respondents. Although they are aware of water scarcity issues during the summer and have a basic understanding of the concept of reusing treated wastewater, most respondents lack sufficient information regarding the quality and possibilities of using such water for irrigation in agriculture. The conclusion underscores the need to educate stakeholders to support the sustainable application of treated wastewater in Istria County's agriculture.

Keywords: water reuse, agriculture, resource management, climate change, drought

1. Introduction

Agriculture represents a major sector within the biotechnical sciences and is a substantial consumer of water resources. Water is indispensable for human survival, as well as for economic and urban development. The global demand for agricultural irrigation is high, and factors such as limited precipitation and water scarcity exert significant pressure on food availability and security. As an exhaustible resource, the sustainable management of water is crucial. Anticipated climate change is expected to exacerbate the need for irrigation and intensify water shortages, thereby adding further stress to both water and land use. Current water resource management practices are unsustainable; without the implementation of effective, sustainable management strategies aimed at water conservation and optimization, the viability of existing water resources will be compromised.

According to the data of the European Environmental agency, the total use of water in agriculture accounts for more than 50% (European Environmental Agency, 2023.). In the world, about 18 % of arable land is irrigated and on these lands about 40 % of the total food is produced (Hofwegen and Svendsen, 2000.), In 2016, 8.9% of utilised agricultural area in the EU was irrigable, 15.5 million hectares, but only 5.9% was irrigated, 10.2 million hectares (Eurostat,2016.). According by the authors, water can be considered a unique and irreplaceable natural resource with limited quantities and uneven spatial and temporal distribution. The connection with the importance of water can be seen from the evolutionary progress of living organisms, all the way to sociological and cultural human activities throughout history (Water Management Strategy 2008.). Today, the need for water is increasing due to the factors of population growth, urbanization, and globalization, but today there is a great possibility of endangering water resources and ecosystems. Water can be a limited development factor, but also a threat to the health and sustainability of the ecosystem. Istria County, similar to many Mediterranean regions, faces the pressing issue of water scarcity. This challenge is intensified with the influx of tourists during the peak season, which coincides with the crop-growing period. This simultaneous demand for water from both tourism and agriculture highlights the importance of effective water management in the region. The reuse of treated wastewater in agriculture can not only alleviate pressures on freshwater sources but also provide essential nutrients for crop growth. However, the success of any wastewater reuse project in agriculture hinges not just on its technical viability but also on its social acceptance. The perception and acceptance of such practices by the community, particularly those residing in proximity to these projects, can significantly influence the feasibility and successful implementation of wastewater reuse initiatives. This survey, conducted as a part of this research, aims to explore wastewater management aspects within Istria County. Wastewater holds a potential as a resource for sustainable agriculture. Reusing treated wastewater can alleviate pressure on freshwater sources, boost crop yields, and enhance agricultural resilience in the face of climate changes. The survey serves as a data collection tool, gathering insights from county stakeholders.

Agricultural producers provide practical experiences, local leaders offer regional policy insights and challenges, and scientists share expertise in sustainable agriculture and wastewater treatment (Khan, 2022.). The outcome of this survey is to assess the current state of wastewater management in Istria County, understand the challenges faced by diverse stakeholders, and explore sustainable practices. This research aims to facilitate decision-making, community involvement, and policy development, elements for balancing agricultural prosperity and responsible environmental guidance.

2. Aims

The aims of this thesis were to:

1. Present the problems and advantages of wastewater reuse (WWR) in agriculture.
2. Evaluate EU strategy and guidelines for safe reuse of wastewater in agriculture.
3. Evaluate the possibility of reuse of wastewater in agriculture (irrigation) based on the available data on water quality at the outlet of wastewater treatment plants in Istria County.
4. Assess the acceptance of the different stakeholders in Istria County (farmers, citizens, decision makers at municipal and regional level) for the reuse of WWR in agriculture.

3. Literature review

3.1. Irrigation as an Agritechnical Measure in Agricultural Production

Irrigation is one of the most important agrotechnical measures in agricultural production, which is necessary due to climate change, while higher and safer yields are achieved through irrigation. Melioration measure that compensates for the necessary amounts of water when the vegetation lacks enough water in the soil for stable growth and development of cultivated crops (Kantoci, 2012.). Irrigation in modern agricultural production can achieve products of top quality with stable high and quality yields. Irrigation of agricultural production is a well-known melioration measure and practice used by numerous cultures in the past, however, today it still represents an inevitable interdisciplinary measure that enables modern intensive exploitation of agricultural land. Irrigation methods can be underground, surface and raining. Today, sprinkler irrigation and localized irrigation (drip and mini sprinklers) are most often used (Mađar and Šoštarić, 2009.).

Lack of water is one of the main challenges of the 21st century. Today, unprecedented pressures and competition for water resources are omnipresent precisely because of the factors of population growth and mobility, economic development, urbanization, changes in traditional diet, migration, and pollution. The Food and Agriculture Organization (FAO) estimates that more than 40% of the world's rural population in river basins is classified as water scarce. Mediterranean areas suffer from seawater intrusion into aquifers, coastal subsidence, and water pollution, as well as increasing demands for water in agriculture (Somot et al., 2008., Füssel, 2012.).

According to Dastane (2010.), in their work on water resources, and as mentioned by the Food and Agriculture Organization (FAO), countries in the Middle East, North Africa, and Central Asia are ranked in the critical water deficit sector (Dastane, 2010.). The situation is increasingly serious and worsened by the significant effects of climate change and the demands for bioenergy in the world. Irrigation is a significant user of clean water in the world, with an average of 70% - 90% water exploitation, especially in highly developed countries (Dastane, 2010.).

Israel is considered a country with an absolute shortage of water (<500 m^3 per year per inhabitant). Water management in Israel is characterized by limited sources of fresh water, poor natural distribution of these resources, and a distributed and growing population. Israel is one of the countries in the world that has invested impressive efforts and resources to deal with water scarcity. Over the years, Israel has accumulated considerable knowledge and developed effective strategies to encourage productive agriculture in the context of water scarcity. Through national water programs, efforts have been made to promote irrigation research, efficient irrigation technologies, close monitoring of water withdrawals, and training and technical assistance to farmers. Despite this, Israel has become a global leader in innovative water technology industries (Dastane, 2010.).

Israel is one of the most densely populated countries in the world and is characterized by arid and semi-arid climatic conditions. The main constraints of the country include frequent droughts, desertification of agricultural land, rapid urbanization, depletion of resources, technological uncertainty and high costs of non-conventional sources, deterioration of water quality and increased lack of water. Among these constraints, water scarcity is the primary limiting factor in Israeli agriculture, with the country dependent on irrigation. The main type of irrigation systems in agriculture is drip irrigation, this has the highest rate of water efficiency in agriculture, reaching a rate of 70 to 80%, compared to other irrigation systems that reach 40%. Recycled water use, wastewater, nutrient addition mixed with water, and desalination are recent new innovations used to address water scarcity in Israel (Megersa and Abdullahi, 2014.).

Saudi Arabia is the largest country in the world without lakes and rivers (Llamas and Custudio, 2003.), it derives over 80% of its water supply from groundwater and collects and processes 672 million m^3 of wastewater per day, but less than 20% is reused (Al-Musallam, 2006.). Although the agricultural sector is by far the largest user of water in Saudi Arabia and perhaps offers the greatest scope for water conservation, most wastewater is generated outside the agricultural sector (Qadir et al., 2010.), and the growing urban population discharges larger volumes of wastewater. Respectable significance for Saudi Arabia is the use of waste and industrial water, and desalination (Keraita et al., 2004.). According to FAO (2010.), even some of the poorest countries in the world, Gambia, Ivory Coast, Mali, and Niger, have in recent decades devoted considerable importance to the rehabilitation and development of irrigation systems as a means of increasing production, improving food security, and increasing resilience to climate change.

One example is found in Namibia's capital, Windhoek, where drinking water supplies have increased in dry areas by treating wastewater in a practical and responsible manner. Due to its geographical location in South Africa, Namibia particularly suffers from extreme drought as deserts or semi-deserts make up more than 80% of its territory, therefore the lack of potable water has been one of the key problems in the country (Lahnsteiner and Lempert, 2007.). Since 1968., wastewater has been treated and mixed with drinking water, to solve the previously mentioned problem. After many renovations and improvements over several years, the resulting efforts resulted in water of satisfactory quality, confirmed by detailed chemical, bacteriological, virological, and epidemiological research.

According to statistical data from the European Commission (2016.), within Europe there is a large imbalance in the availability of water resources, and thus significant spatial variability in agricultural practices and water consumption. The main factor is climate, which dictates water consumption in agriculture. Europe is divided into regions where irrigation is the only source of water for growing crops due to the dry summer months, or irrigation is mostly used as an agrotechnical measure.

According to the available Eurostat data from 2016., 8.9% of the used agricultural area in the EU was irrigated (15.5 million hectares), but in fact only 5.9% (10.2 million hectares) was irrigated. In 2016., Spain (15.7%) and Italy (32.6%) had the highest share of irrigated areas in EU agricultural areas.

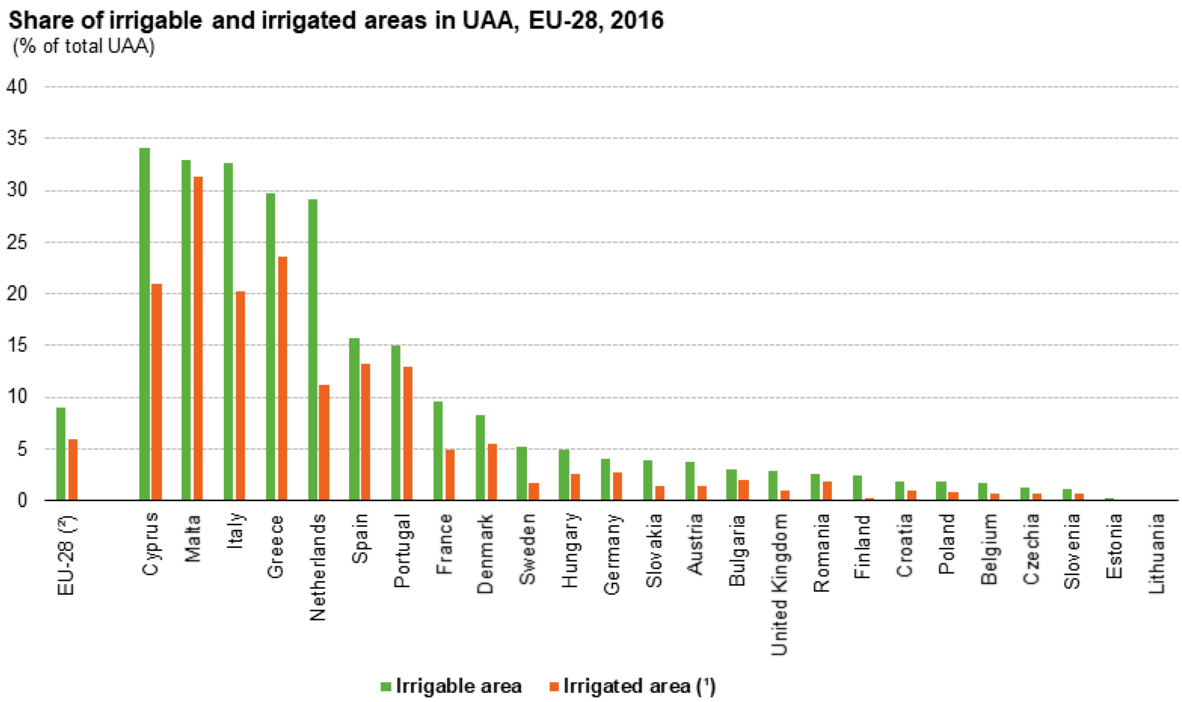


Figure 1. Irrigated land area in EU.

Source: Eurostat, accessed 20th September 2023.

Favourable agroclimatic conditions, rich water resources and fertile agricultural land created good conditions for the development of irrigation systems. Despite this, Croatia, compared to EU member states, is at the bottom of the scale with irrigated agricultural areas, however, Croatia has a slight tendency to increase the share of irrigated areas in future, after years of stagnation. Through the implementation of the National Project of Irrigation and Agricultural Land and Water Management, the irrigated areas in Croatia increased by more than 50% in two years, so that in 2007, approximately 15,000 ha of agricultural areas were irrigated. Accordingly, in 2008, a sharp decline in irrigated areas was recorded (EUROSTAT, 2016.). The reason for this is the large world economic crisis recorded in the period of 2008. According to the National Bureau of Statistics, the crisis also manifested itself in Croatia, initially by halting economic growth, then by reducing production and consumption, and by a significant drop in GDP of 5.8% (Državni zavod za statistiku [DZS], 2010.).

Croatia needs to work towards the development of sustainable irrigation. One of the important national projects aimed at the development of irrigation in the Republic of Croatia is for Irrigation and Management of Agricultural Land and Water, and the last 15 years have been invested in the construction of new irrigation systems and the rehabilitation of existing ones, thereby enabling safe and stable agricultural production. In recent years, irrigation is included in the Measures of the Rural Development Program of the Republic of Croatia 2014-2020, and thereby provided financial instruments for the construction of the irrigation system from the European Agricultural Fund for Rural Development. According to the Water

Management Strategy (Croatian Official Gazette, 107/95. and 150/05.) in the Republic of Croatia, irrigation primarily relies on surface water from lakes and rivers, although groundwater exploitation is also prevalent. Although, there are adequate areas for irrigation and a rich water resource, a small number of irrigation concessions have been issued.
In general, the sources of irrigation water can be different. They are most often applied:
- water from open streams, lakes, and springs
- underground water
- water accumulated in natural and artificial reservoirs.

Šoštarić and Mađar (2009.) argue that rainwater is the optimal source for irrigation, but it is often insufficient for large-scale agricultural production. Before using any water source, a chemical analysis is essential, and periodic testing during the irrigation season is advisable. The water regime, including factors such as flow rates, sediment transport, and chemical composition, significantly influences the entire ecosystem (Ožanić, 2007.).

All the mentioned factors have a strong influence on the entire ecosystem. It is important to avoid stress for the plants, for example, irrigation with unsuitable temperatures, for most crops the most suitable temperature is 25°C during the growing season. Suboptimal temperatures have a detrimental impact on plant development and nutrient absorption. They also adversely affect the microbiological processes in the soil. Surface water, typically warmer, is often a preferred source for irrigation as compared to underground water. In instances where groundwater is utilized, reservoirs for tempering are advisable, especially for systems relying on sprinkler irrigation. To maintain average and stable yields, it is crucial to manage optimal soil moisture throughout the growing season. This involves professional maintenance routines aimed at preserving optimal humidity levels in the soil. Additionally, it is important to secure a water source of sufficient quantity and acceptable quality to improve irrigation performance.

While most regions in continental Croatia and parts of Istria meet water quality standards for irrigation, challenges arise in areas such as Kvarner, Dalmatia, and the islands where the water can be saline and alkalized (Romić and Zovko, 2014.). An emerging alternative in such cases is desalinated water, produced by eliminating salt and other minerals through techniques like distillation or reverse osmosis. Despite its potential, desalination remains costly and energy-intensive, limiting its widespread adoption. Quality assessment of irrigation water is not a singular event but a continuous process (Romić and Zovko, 2014.). It involves evaluating the changes that will occur in the soil upon water application and understanding potential implications for both soil and plant health. Key parameters include salinity, alkalinity, and ion toxicity. These parameters can influence soil structure, permeability, and the availability of biogenic elements to the plant. Issues like ion toxicity and heavy metal concentration could cause significant damage to plants, reducing yields. Salinity levels can influence plant development through osmotic pressure, affecting the soil's water-holding capacity. Pathogenic organisms present another concern, particularly when purified wastewater is used for irrigation.

With a rising global population and a limited scope to increase arable land, the importance of efficient and sustainable irrigation systems cannot be overstated. It will play a critical role in ensuring an adequate food supply in the foreseeable future.

Alternative water resources for irrigation include saline springs and seawater treated through desalination technology. Desalination involves the removal of salts and other mineral constituents from water, typically via distillation or reverse osmosis processes. Although this treated water becomes suitable for various consumption needs, including irrigation, the adoption of desalination technology remains limited due to its high operational costs, energy-intensive nature, and infrastructural demands (Jelić Mrčelić, 2007.).

The evaluation of water quality for irrigation is of paramount importance, aiming primarily to anticipate the alterations in soil properties and potential repercussions on plant health following water application. According to guidelines outlined by Ožanić (2007.) primary concerns related to irrigation water quality include salinity, alkalinity, and ionic toxicity.

- In terms of alkalinity, a heightened sodium content can negatively impact the soil structure, affecting its infiltration capacity and permeability. This, in turn, restricts the availability of essential biogenic elements to the plants.
- Toxicity from ions and heavy metals presents another considerable concern, certain ions, when absorbed by plants from the soil or water at harmful concentrations, can induce physiological damage, consequently leading to yield reduction (Romić and Zovko, 2011.).
- salinity, by increasing the level of salt, it affects plant development through osmotic pressure, which is connected to the total concentration of salt and reduces the amount of accessible water in the soil (Ondrašek et al., 2010.).

The utilization of treated wastewater in agricultural practices introduces the potential concern of pathogenic organisms, which can pose significant challenges and risks to both crop cultivation and public health, necessitating comprehensive monitoring and treatment measures to ensure the safety and viability of such wastewater reuse initiatives.

With continued population growth and limited potential to increase suitable arable land, irrigation is becoming an increasingly important means of ensuring sufficient global food supply in the future.

In Croatian agronomic practices, water quality classification for irrigation commonly adheres to the standards set forth by the Food and Agriculture Organization (FAO) in 1985. Such standards offer a considerable range of classifications aimed at addressing the multifaceted issues tied to water quality in irrigation systems.

Croatia is a country rich in water supplies, although its availability is unevenly distributed. This is reflected in a relatively unfavourable spatial and intra-annual distribution, which is particularly pronounced during the dry part of the year in the coastal area. In the last ten-year period, the quality of underground and surface water did not change significantly (Environmental Protection Agency, 2011.).

3.2. Wastewater

Natural water that has been used for a specific purpose, during which the quality of the water itself changes, is called wastewater. It is created by the introduction, discharge or disposal of nutrients and other substances, thermal energy, and other causes of pollution in quantities that change the properties of water in relation to their ecological function and intended use (National Water Protection Plan, Croatian Official Gazette, 8/99). Through field sampling and laboratory analysis, the content of certain polluting substances in wastewater is determined, on which further planning and designing of the wastewater treatment plant follows. As a result of economic development and population growth, the amount of wastewater is also increasing. To protect the quality of natural water systems, it is necessary to meet certain quality conditions before discharge into the recipient by means of treatment. Wastewater can be divided into:

- Household
- Industrial
- Municipal
- Landfill leachate
- Polluted rainwater

The removal of pollutants by individual processes or their combination is evaluated as a treatment effect, as the ratio of the achieved reduction in the concentration of the pollutant to the concentration of the same substance in the wastewater inflow. The efficiency of the wastewater treatment plant depends on the stage of treatment. For each stage of treatment, individual facilities and equipment are foreseen, as well as additional equipment that must contribute to the permanent removal of waste materials from polluted water in an appropriate manner. The planning of technological process lines depends on the amount and composition of wastewater, but also on the requirements related to the water being processed. When urban wastewater is treated, physical and biological processes are most often used, along with the application of various sludge treatment processes (Tušar, 2009.). The choice of wastewater treatment process before discharge into the environment mostly depends on the quantity and type of wastewater, but also on the required water quality at the point of discharge. Different procedures are usually combined so that the effect of each individual procedure or their combination gives the best possible results.

Wastewater can be treated using:

- physical wastewater treatment procedures that include precipitation or sedimentation, flotation, filtration, degassing, and desilting
- chemical procedures that include precipitation, adsorption, and disinfection
- biological procedures that include the use of activated sludge, biofilters and others microorganism carrier with the aim of implementing nitrification, denitrification, and phosphorus removal.

Physical processes are actions that remove large dispersed and floating waste substances from wastewater using grates. Further procedures include settling or sedimentation of solid particles using gravity in sand pits and flotation in an oil well, in which substances are separated from the liquid by rising to the surface, from which they are then separated. Procedures in sand pits and oil pits are mandatory, and they are also called preliminary wastewater treatment procedures (Tušar, 2009.).

Physicochemical and chemical processes include:

- procedures without chemical changes to the ingredients (filtering, adsorption, irradiation, reverse osmosis, distillation),
- procedures with chemical changes of ingredients (neutralization, flocculation, coagulation, chemical precipitation, ion exchange, oxidation).

The following processes are used in the treatment of municipal wastewater: sieving, equalization, mixing, settling (sedimentation), floating (flotation), squeezing (filtering), adsorption, aerobic and anaerobic processes, nitrification and denitrification, and phosphorus removal. The biological process of wastewater treatment is the decomposition of organic substances with the help of microorganisms, and it takes place spontaneously in nature. Microorganisms, most often bacteria, absorb organic pollution and nutrients that are dispersed or dissolved in wastewater (Tušar,2009.).

Decomposing microorganisms can be divided into groups according to Tušar (2009.):

Group 1. according to the need for oxygen:

- aerobic microorganisms, which need oxygen dissolved in water for life
- anaerobic microorganisms, which can live without oxygen dissolved in water
- facultative microorganisms, which can live with or without oxygen dissolved in water

Group 2. according to the type of metabolism:

- autotrophic organisms, which use solar energy and inorganic substances and produce new organic compounds
- heterotrophic organisms, which use organic compounds

Systems for the collection of wastewater or sewage networks are systems that are organized for the treatment of wastewater. The system is designed primarily for the protection of people and the health of the environment. Although their benefits are broad, there are other aspects of this infrastructure and associated technologies that are advancing intensively. The treatment reduces the amount of wastewater, and such water can be discharged into the environment without unwanted consequences on the environment.

According to the Water Act (Croatian Official Gazette, 66/2019.), appropriate treatment means the treatment of wastewater by procedures, and after the first and second stages, it must be additionally treated in such a way that, before releasing the treated wastewater into the environment, a representative sample can be taken before and after the wastewater treatment. Treated wastewater can be reused without harmful consequences for the environment.

3.3. Wastewater treatment processes

Depending on the stage of treatment and the procedures applied to the treatment systems, the following procedures can be distinguished:

- preliminary
- first stage (primary)
- second stage (secondary)
- the third stage (tertiary)

Table1. Overview of actions and procedures on wastewater treatment systems

Preliminary	1st stage	2nd stage	3rd stage
- Screening - Shredding - Sand and grease removal	- Removal of dispersed matter Sedimentation Floating - Pressing on micro sieves	- Removal of biodegradable matter - Biological procedures - Physicochemical procedures	- Removal of nitrogen and phosphorus - Removal of persistent organic matter - Removal of heavy metals and dissolved inorganic matter

Source: EU - Lex, Regulation on minimum requirements for water reuse, 2020.

According to article 3 of the regulation (Regulation (EU) 2020/741, 2020.) on wastewater emission limit values, article 3. “Preliminary treatment” is defined as the pre-treatment of wastewater from which large, dispersed, and floating waste substances (gravel, sand, leaves, oils, and fats) are removed. The preliminary treatment process includes the use of coarse and fine sieves to remove impurities that may interfere with the operation of the device or cause clogging. The size of the openings on the grates is chosen depending on the size of the waste material that we want to remove. Smaller particles (sand and gravel) are removed by the process of sedimentation in devices called sand catcher. Oils, fats, and other substances that have a lower density than water, are removed in grease traps, in which air bubbles are released from the bottom of the tank, which adhere to the particles and thus take them to the surface.

After the preliminary treatment, the first stage of treatment follows, which implies the treatment of municipal wastewater by physical and/or chemical procedures, whereby the BOD_5[*] of the incoming wastewater must be reduced by at least 20%, and the total suspended

[*] BOD_5 Five-day biochemical oxygen demand. The total amount of oxygen used by microorganisms decomposing organic matter increases each day until the ultimate BOD is reached, usually in 50 to 70 days. BOD usually refers to the five-day BOD or BOD_5.

matter by at least 50% before discharge (Croatian Official Gazette, 8/99). This procedure is mainly based on the sedimentation process, and it is carried out in such a way that the wastewater remains in the sedimentation tank for a certain period to achieve the desired separation of suspended substances. By applying some additional methods, such as coagulation and flocculation, a faster and more effective sedimentation is achieved. Coagulation is the process of disturbing the aggregate stability (equilibrium) of particles in wastewater using coagulants (aluminium sulphate, iron sulphate, iron chloride and lime). Flocculation is the process of combining colloidal particles, previously destabilized by the coagulation process, into larger particles (floccules) that settle much faster (Poltak, 2005.).

The second stage of treatment includes biological treatment of municipal wastewater with secondary sedimentation or other procedures that reduce the concentration of suspended matter and BOD_5 by 70 to 90%, and the concentration of COD* by at least 75% (Croatian Official Gazette, 8/99). Some of the processes that belong to this stage of treatment are the activated sludge process, lagoons, plant treatment systems. The process based on the principle of activated sludge belongs to the group of systems with the second stage of treatment, which is most often preceded by the processing procedures of the previous and first stages. This process includes the application of biomass of living microorganisms that are mixed with wastewater thus forming activated sludge. For biological processes to take place, a constant supply of oxygen is necessary using surface aerators and mixers or by blowing air into the tank through submerged diffusers. In this way, microorganisms are enabled to carry out the process of oxidation of organic carbon, during which carbon dioxide (CO_2) and water are formed (Drenowski, 2019.). After aeration, the mixture of wastewater and activated sludge is collected in a secondary settling tank, which is shaped in the form of a funnel for easier and faster sedimentation of sludge particles. During settling, the sludge collects at the bottom of the funnel due to its weight, while the water is drained towards the control measuring shaft and then towards the recipient. Part of the mass of settled activated sludge, which consists of microorganism floccules, is returned from the secondary settling tank to the bio reservoir, while the excess sludge is taken away for sludge treatment before disposal. After analysis, waste sludge can be used as a high-quality fertilizer in agriculture. The treatment system based on activated sludge is suitable for the treatment of wastewater of smaller settlements, business zones, tourist complexes and similar contents with a capacity of up to 2000 PE (Population equivalent) (Kardum, 2008.).

Sequential batch reactor (SBR) is a system for biological treatment of wastewater that works on the principle of activated sludge. The main difference compared to conventional devices with continuous flow is that all steps are performed in one reactor, and processing is done in batches, i.e., with interrupted flow, which is why this type of device is suitable for smaller systems. Given that the inflow of wastewater is continuous, there is often a need to

* COD Chemical oxygen demand measures the amount of oxygen required to chemically oxidize the organic material and inorganic nutrients, such as Ammonia or Nitrate, present in water.

install several SBR reactors in which different phases of wastewater treatment take place. The biological process takes place in the same way as in conventional treatment plants, where microorganisms break down the organic content of wastewater. Aeration systems ensure oxygen supply during the process of oxidation of organic substances. The aeration process is followed by a phase of sedimentation followed by the discharge of treated water, while excess sludge is removed from the bottom of the tank using a pump. After that, the tank is refilled with wastewater and a new cycle begins (Poltak, 2005.).

Membrane biological reactor (MBR) is a technological solution for wastewater treatment that combines processes based on the principle of activated sludge with a membrane filtration system. Depending on the desired stage of separation, microfiltration, and ultrafiltration membranes with a pore size of 0.01 µm to 10 µm are used, which can be located outside the reactor or can be immersed in the bioreactor, so the processes of biodegradation and separation take place in the same reservoir (Serdarević, 2014.). The membrane of the biological reactor serves as a selectively permeable barrier where the particles are separated based on the difference in size and shape. The part of the liquid phase that has passed through the membrane is called the permeate, while the concentrate is the part in which the concentrated dissolved substances remain. Mechanical pre-treatment of wastewater is necessary in MBR systems to prevent membrane failure and clogging. One of the main advantages of using this wastewater treatment system is that large amounts of water can be processed in a small space and that such water is of very high and uniform quality (Mijatović and Matošić, 2015.).

In the case when the use of public drainage systems and the treatment of municipal wastewater with conventional systems create excessive costs, some other individual small systems can be used which will achieve equal protection of the water environment. Examples of such wastewater treatment systems are soaking fields, underground filtration, lagoons, oxidation canals and artificial wetlands or plant devices, which are mainly used in rural areas due to their large surface area. The principle of treatment with a biological treatment system is based on a combination of biological, physical, and chemical processes. These processes imitate the processes in nature and in this way process, i.e., treated wastewater. The biological treatment system consists of one or several pools that are built with a slight slope and through which wastewater passes. The bottom of the pool is covered with an impermeable foil or loam, and on that substrate goes the substrate in which indigenous plants such as cane, sedges or cattail are planted (Šperac et al., 2013.).

The use of plant treatment systems is common in many developed European countries such as Germany, Great Britain, France, Denmark, Austria, Poland, and Italy (Stanković, 2017.), and it is important to note that the use of such devices is constantly increasing. Plant treatment systems are beginning to be used more and more often in Croatia, and some of the larger ones are Vinogradci, Hruščica, Žminj in Istria, Glavotok autocamp on Krk, Bijar autocamp on Cres, Jakuševac plant device (Šperac et al., 2013.).

Today, the awareness of the protection and preservation of the environment is more and more developed, this mainly contributed to the dynamic development of wastewater utilization technologies and treatment according to environmental protection laws. The definition of a wetland is that it is a special ecosystem where water is the primary factor controlling the environment and the flora and fauna (Ramsar Convention Secretariat, 2016.). Wetlands are of extreme importance due to their biological properties, functions, and economic values. They are extremely important in the regulation of hydrological flows (Figure 2- and Figure 3.), which guarantee the renewal of groundwater and participate in the regulation of erosion due to the retention of sediments. Using this knowledge, in the early 1950s at the German Max Planck Institute, the first experiments and research on the application of wetland for the purpose of natural wastewater treatment in artificial wetlands, which we now call plant treatment systems (Vymazal, 2010.). Currently, research and experiments on plant treatment systems remain applicable on a global scale. (Šperac et al., 2013.).

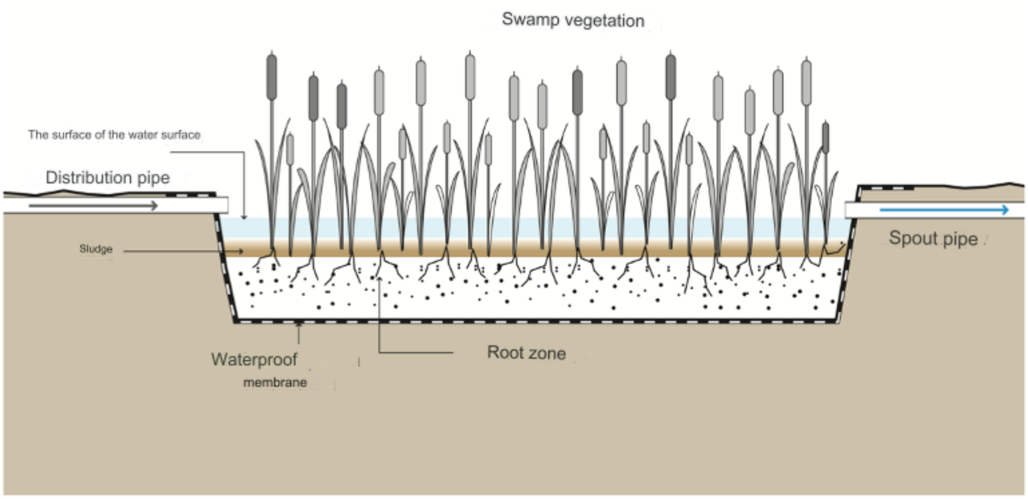


Figure 2. Schematic overview of the plant treatment system with a free water surface.
Source: Malus and Vouk, 2012., accessed 20th September 2023.

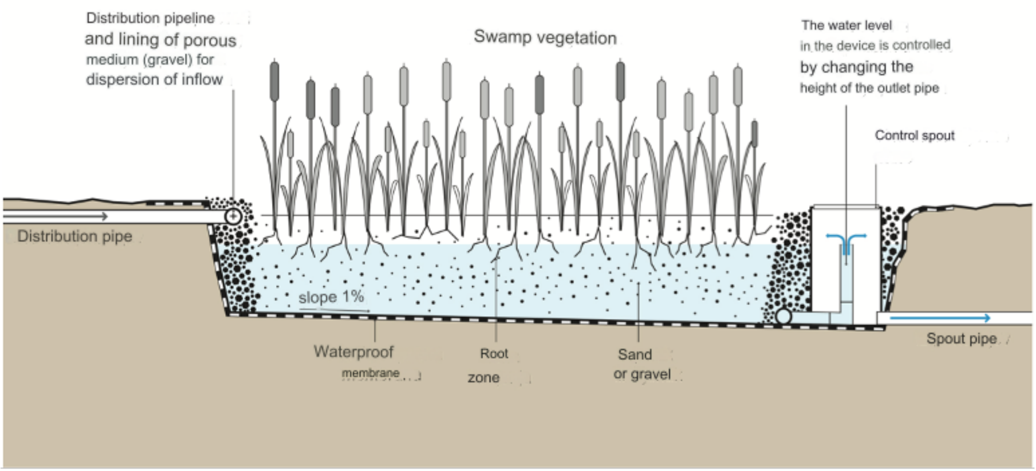


Figure 3. Display of plant treatment system with horizontal subsurface flow.
Source: Malus and Vouk, 2012., accessed 20th September 2023.

Wastewater treatment with plant treatment systems is a technology that is applied in natural ecosystems such as swamps, marshes, and wet fields, in artificial ponds and lagoons, for the special purpose of treating water in constructed wetlands. Constructed wetlands come in different designs with different flow characteristics (Kadlec, 1987., Wissing, 1995.). Plant treatment systems are constructed in a way that imitate natural processes with the purpose of creating conditions that improve the treatment of wastewater that flows through them (Malus and Vouk, 2012.). Plant treatment systems are inspired by wetlands, vegetation, soil, and microorganisms that live in wetlands and thus purify water. When choosing vegetation, it is necessary to choose autochthonous marsh plants (Malus and Vouk, 2012.). Plant treatment systems consist of one or more basins, through which wastewater passes and is treated using biological, physical, and chemical processes (Šperac et al., 2013.). These wetlands have evolved over the past five decades into a reliable treatment. Today, such systems are easy to use, low costs of construction and low maintenance. The system can be used to treat all type of wastewater. It is extremely suitable for use in undeveloped and rural areas where there is no built sewage system. Maintenance of plant treatment system is simple and does not require electricity (Vymazal, 2010., Vučinić et al., 2011.). Natural methods of wastewater treatment are an alternative to technical and conventional methods for wastewater treatment (Šperac et al, 2013.).

Table 2. Limit values of emissions of municipal wastewater treated at the systems of the second stage (II)

Indicators	**Threshold value**	**The lowest % of pollution reduction**	**Reference measurement method**
Total suspended solids	35 mg/l	90	Filtration of the test sample through 0.45 µm membrane filtration. Drying at 105 °C and weighing. Centrifugation of the test sample (at least five minutes with medium acceleration from 2800 to 3200 g), drying at 105 °C and weighing.
Biochemical consumption of oxygen BOD_5 (20 °C) without nitrification	25 mg O_2/l	70	Homogenized, unfiltered, undecanted sample. Determined dissolved oxygen before and after five days of incubation at 20 °C ±1 °C, in complete darkness. Nitrification inhibitor addition.
Chemical consumption of oxygen KPK	125 mg O_2/l	75	Homogenized, unfiltered, undecanted sample. Potassium dichromate

Source: Croatian Official Gazette, number 66/2019.

The third stage is the strictest municipal wastewater treatment process, which is used in cases where it is necessary to meet special criteria for treated wastewater. In this stage, physical-chemical, biological, and other procedures are combined, which reduce the concentration of nutrients and remove other special indicators of waste substances to the prescribed values, depending on the size of the system. It is mainly about removing nitrogen and phosphorus.

Table 3. Limit values of emissions of municipal wastewater treated on the systems of the third (III) stage

Indicators	**Threshold value**	**The lowest percentage of pollution**	**Reference measurement method**
Total phosphorus	2 mg P/l (10,000 to 100,000 PE) 1 mg P/l (> 100,000 PE)	80	Molecular absorption spectrophotometry
Total nitrogen (organic N+NH_4 -N + NO_2 -N+NO_3 -N)	15 mg N/l (10,000 to 100,000 PE) 10 mg N/l (> 100,000 PE)	70	Molecular absorption spectrophotometry

Source: Croatian Official Gazette", number 66/2019.

3.4. The EU's Urban Wastewater Treatment Directive

According to the EU Commission urban wastewater is one of the main sources of water pollution if it is not collected and treated according to EU rules. Wastewater contains organic matter, nitrogen and phosphorous which are all removed through the treatment process in the treatment plant. It also can be contaminated with harmful chemicals, bacteria, and viruses which, when untreated and discharged into the environment, affect our health, and damages our rivers, lakes, and coastal water (European Commission, 2022.).

EU legislation sets binding standards for all its members to ensure high quality drinking water and limit pollution caused by wastewater. Member States must regularly report on key water quality parameters and ensure that all significant domestic and industrial wastewater discharges undergo collection and treatment. Also, the quality of water suitable for bathing has been defined and requirements have been set for the quality of drinking water to protect human health. The acts are the backbone of the joint efforts of the member states in ensuring public health and environmental protection throughout Europe in the field of water management. Different directives have specific roles in delivering their objectives. Instead of fulfilling a specific goal of an individual directive, considering the interactions between directives can lead to several advantages, such as better integration of needs in creating cost-effective measures to improve the status and quality of our waters (European Commission, 2022.). According to the urban wastewater treatment directive (Council Directive 91/271/EEC, 1991.) refers to the collection, treatment and discharge of municipal wastewater and the treatment and discharge of water from certain industrial sectors. The Water Management Departments for the middle and lower Sava River and the Danube and lower Drava River have the highest ratio of constructed systems that meet the requirements of the directive. The Water Management Department for the upper Sava has the lowest number of systems that meet the requirements. The Directive (91/271/EEC) also stipulates in Article 12: "Treated wastewater shall be reused whenever possible. The methods of discharge of wastewater must minimize harmful effects on the environment" (European Commission, 2022.). The Council Directive (91/271/EEC), commonly known as the Urban Wastewater Treatment Directive, stipulates regulations for urban wastewater management within the European Union. It mandates the collection and treatment of wastewater in urban areas inhabited by more than 2000 people, with a particular emphasis on secondary treatment for discharges from such urban areas. Furthermore, urban areas exceeding 10,000 residents located in catchment areas with sensitive waters are required to implement advanced treatment processes. The directive also imposes pre-authorization requirements for various wastewater discharges, encompassing those from the food-processing industry and industrial sources into urban wastewater collection systems. Rigorous monitoring of treatment plant performance and receiving water quality forms an integral part of compliance. Additionally, controls are enforced concerning sewage sludge disposal, reuse, and the potential reuse of treated wastewater (European Commission, 2022.).

In a significant development, the directive underwent a substantial revision on 26 October 2022, following an evaluation and an impact assessment. The primary objectives of this revision include the reduction of pollution levels, energy consumption, and greenhouse gas emissions. It aims to enhance water quality by addressing residual urban wastewater pollution, particularly in areas not previously covered by stringent treatment standards. Furthermore, the revised directive strives to improve access to sanitation, with a focus on vulnerable and marginalized communities. It introduces the principle of 'the polluter pays,' holding industries accountable for treating micropollutants in their wastewater discharges. EU member states are now required to monitor pathogens in wastewater, further bolstering public health measures. This revision also envisions a more circular approach within the urban wastewater sector (European Commission, 2022.).

The anticipated impacts of these new rules by 2040 are profound, with projected annual savings of nearly EUR 3 billion across the EU. Additionally, there is an expected reduction in greenhouse gas emissions by over 60% compared to 1990. levels, a decrease in water pollution exceeding 365 thousand tonnes, and a significant reduction in microplastic emissions by 9%. The evaluation conducted in 2019. underscored the directive's overall effectiveness when fully implemented. Notably, improvements in water quality throughout the EU have been achieved through the reduction of organic matter and other pollutants in treated wastewater. While the implementation of the directive has incurred costs, the benefits clearly outweigh these expenditures. However, it also highlighted persistent pollution issues not covered by the current rules, including those stemming from smaller urban areas, stormwater overflows, and emerging contaminants like pharmaceutical and cosmetic residues. Moreover, the urban wastewater sector represents one of the most substantial energy consumers in the public domain, offering significant potential for reducing greenhouse gas emissions (European Commission, 2022.).

3.5. Regulations on wastewater emission limit values

The regulations on wastewater emission limit values are a legal document that sets out the maximum concentrations of pollutants that are allowed to be discharged into water bodies from industrial and municipal wastewater treatment plants. The purpose of the regulations is to protect the environment from pollution and to ensure the quality of water resources. The regulations stipulate emission limit values, (Table 4.), for wastewater (Croatian Official Gazette, 26/2020.), prior to its release into public drainage systems, septic or collection pits, and any discharge into natural water bodies, along with provisions for temporary permissions to exceed the specified discharge quantities and emission limit values. Additionally, these regulations establish criteria and conditions for the collection, treatment, and discharge of municipal wastewater, as well as exceptions for permitted discharges into groundwater. They also define the methodology for sampling and analysing wastewater composition, including the frequency of such sampling and testing. Furthermore, these regulations set forth the permissible concentration levels of quality indicators and stipulate the minimum required reduction in wastewater input loads from treatment plants prior to discharge into natural receptors following a specified degree of treatment (Croatian Official Gazette, 26/2020.).

Table 4. Emission limit values for pollutants in treated wastewater discharges

Stages of treatment	Indicator	Threshold Value	Minimum reduction of input load
I.	Total suspended solids	-	20%
	Biochemical oxygen demand (BOD5) 20°C	-	50%
II.	total suspended matter	35 mg/l (greater than 10 000 PE) 60 mg/l (2 000 to 10 000 PE)	90% 70%
	Biochemical oxygen demand (BOD_5) 20°C	25 mg O_2/l (greater than 10 000 PE) 40 mg O_2/l (2 000 to 10 000 PE)	70%-90%
	chemical oxygen demand (COD)	125 mg O_2/l (greater than 10 000 PE) 150 mg O_2/l (to 10 000 PE)	75%
III.	Total phosphorous	2 mg P/l (10 000 to 100 000 PE) 1 mg P/l (greater than 100 000 PE)	80%
	Total nitrogen (organic N + NH_3 + NO_2 + NO_3)	15 mg N/l (10 000 to 100 000 PE) 10 mg N/l (greater than 100 000 PE)	70%-80%

Source: Criatian Official Gazette 26/2020, 2020., Guidelines on wastewater emission limit values

3.6. The Nitrates Directive

Nitrogen is a crucial nutrient that helps plants and crops grow, but high concentrations are harmful to people and the environment. Clean water is vital to human health and to natural ecosystems and excess nitrogen from agricultural sources is one of the main causes of water pollution in Europe. Nitrates and organic nitrogen compounds from fertilizer and manure enter groundwater through leaching and reach surface water through runoff from agricultural fields. A high level of nitrate makes water unsuitable as drinking water. In rivers, lakes and marine waters, nitrogen, and other nutrients, in particular phosphorus, stimulate the growth of algae. At moderate levels, algae serve as food for aquatic organisms, including fish. However, excessive nutrient concentration in water systems will cause algae to grow excessively. This affects the natural ecosystem and can lead to depletion of the oxygen in the water. This phenomenon, known as eutrophication, has negative consequences for biodiversity, fisheries, and recreational activities. Both phosphorous and nitrogen play a role in eutrophication, but while the main cause of eutrophication in fresh water is phosphorus, it is mainly caused by nitrogen in marine water (Camargo & Alonso, 2006.).

In 1991, the European Commission adopted the Nitrates Directive to protect surface water, groundwater, and coastal and transitional areas from pollution with nitrate from agricultural origin and the Directive brings clear goals and provisions that should be adhered to by all EU members as well as Croatia. The Nitrate Directive was adopted due to increasing water pollution both in Croatia and in other EU countries. The principles of good agricultural practice and the adoption of action programs serve as the main means of preventing further pollution from such sources (Nitrate Directive 91/676/EEC, 1991.).

Member States must identify Nitrate Vulnerable Zones (NVZ) which are areas (Figure 4. and figure 5.) that are affected by nitrate pollution or that could be affected if no measures are taken. Action programmes, including specific measures for minimizing pollution from nitrate, must be implemented in NVZ. Action Programmes must include specific measures for reducing the pollution at the source, and comprise periods of prohibition of fertilizer application, restrictions for application on sloped soils, and on soaked, frozen, or snow-covered soils, restrictions for application near watercourses, limits on the total amount of livestock manure that may be applied to land. Member states must report progress on implementation every 4 years (Nitrate Directive 91/676/EEC, 1991.).

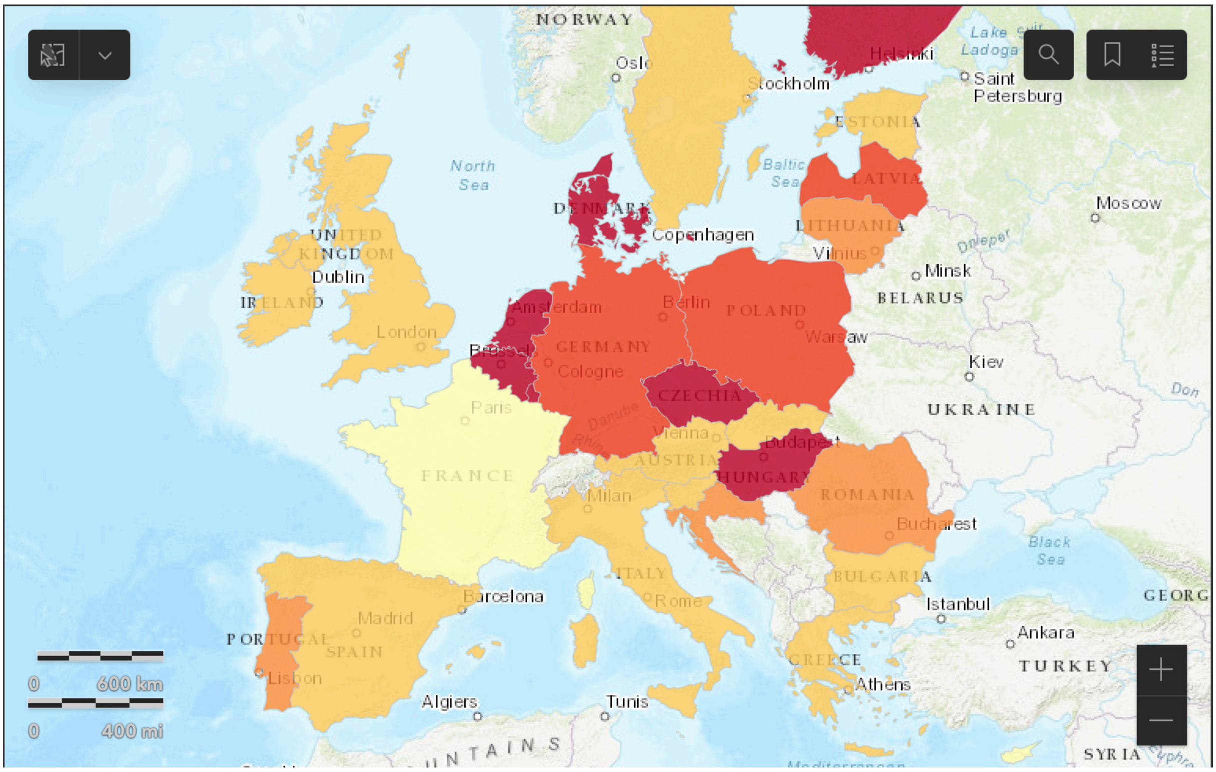


Figure 4. Surface water Monitoring Stations Eutrophication Map.

Source: NITRATES DIRECTIVE - Reporting Period 7 (2016-2019) EU Commission 2016-2019, accessed on 17th September 2023.

This map displays fractions of eutrophic surface water monitoring stations over administrative hierarchy (GISCO-EUROSTAT, 2016.).

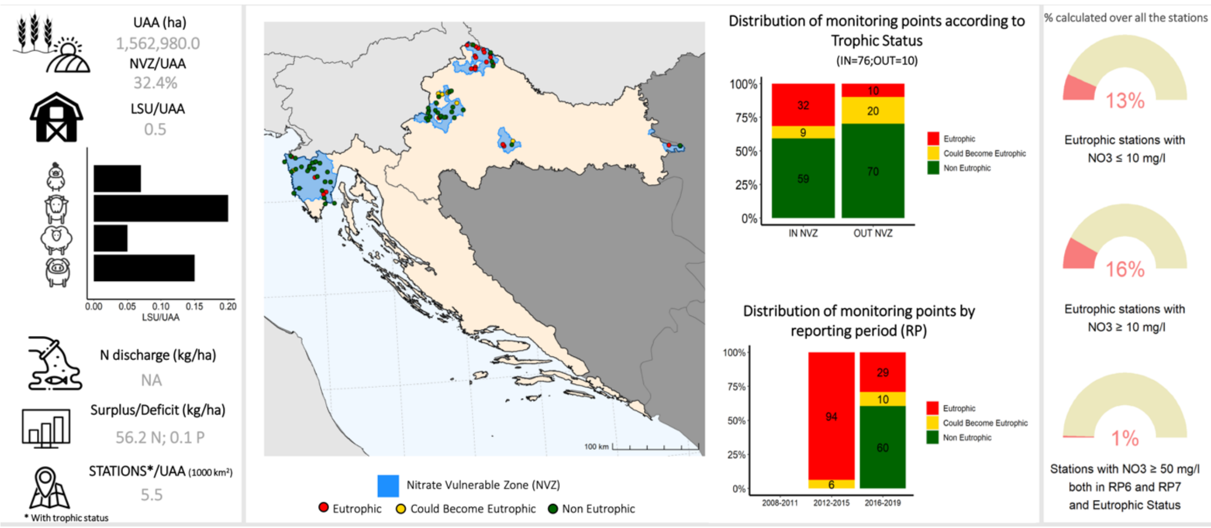


Figure 5. Nitrates Directive Reporting in Croatia.

Source: NITRATES DIRECTIVE - Reporting Period 7 EU Commission 2016.-2019., accessed on 17th September 2023.

The EU has developed an extensive regulatory and policy framework to protect the environment from agricultural pressures. Focusing on the emissions to soil and water, the most relevant directives are the Water Framework Directive, the Nitrates Directive, the Groundwater Directive, and the Drinking Water Directive. Policies like the Common Agricultural Policy and the European Green Deal offer provisions to achieve sustainable agricultural practices while ensuring a level playing field for farmers and preserving food security. Despite this extensive framework, countries face significant challenges to meet the nutrient objectives set. Recent studies show that national implementation often takes place sector at a time, within policy domains such as the water domain or the agricultural domain. As a result, multiple cross-sectoral objectives need to be realised simultaneously at the regional to local level. And although efforts have been made to create linkages between directives, requirements such as monitoring and reporting may be different. Implementation would therefore benefit from more advanced cross-referencing. A good example for this advanced cross-referencing can be found in the recent revision of the Drinking Water Directive by including objectives for the protection of drinking water resources that are linked to the objectives of the Water Frame Directive (Directive 2000/60/EC, 2000.).

3.7. Reuse of treated wastewater and its potential

As the global population grows, so do the needs for water, and the reduction of water resources encourages us to consider the use of alternative water sources, as a supplement to water supply and protection of natural resources. Every so often the use of clean water is common even where water of lower quality can and should be used. One of the possibilities is the reuse of treated wastewater as an effective alternative water supply that can ensure a safe and predictable source of water, while lowering the pressure on water bodies (Morera, 2019.).

Reuse refers to the practice of using something whether its, for its intended purpose or for a different purpose. This approach helps us conserve resources and minimize waste. Reuse plays a role in development, which aims to meet present needs without compromising the ability of future generations to meet their own needs. The water footprint (WF) measures the amount of water utilized in the production of goods and services. It considers direct usage and indirect usage, such as the water required for energy generation during production. The WF is a tool in understanding how our consumption impacts water resources. It enables us to identify ways to reduce our water footprint and make conscious choices. In the realm of wastewater treatment, the WF can help measure the volume of water used during the treatment process, meaning, we can pinpoint areas where we can enhance process efficiency and decrease our water footprint. Ultimately our goal, in wastewater treatment should be safeguarding health and preserving nature while also minimizing resource consumption and waste generation. This goal can be accomplished by implementing methods, for treating wastewater and minimizing the volume of wastewater produced (Morera, 2019.).

The carbon footprint is the amount of carbon dioxide and other greenhouse gases emitted during the process. Wastewater treatment processes require a lot of energy consumption, which results in an increase in the carbon footprint, for example due to aeration during biological treatment. The water footprint measures the amount of water in cubic meters on an annual level (m^3/year) that is used for a process where direct or indirect use of water is required. It also includes water consumption and pollution during each process from distribution to the end user. The water footprint consists of three components: green, blue, and grey. Sources of water such as precipitation (green water), surface/ground water (blue water) and quantities of fresh water needed by end users (grey water). By measuring the amount of water consumed in a process, it is known whether drinking water resources are being used productively, as well as how much polluted water was produced from each litre of water consumed (Morera, 2019.).

In a focused assessment on wastewater treatment's role in reducing water footprint, this study (Morera, 2019.) examines a plant with a daily processing capacity of 4,000 m^3. Three operational scenarios are scrutinized: (I) the direct discharge of untreated wastewater, (II) implementation of secondary treatment protocols, and (III) execution of tertiary treatment methods.

The methodology comprises four key steps, starting with the definition of the study's objectives and scope, followed by the selection of water footprint types to be measured (i.e., blue and green water). Subsequent data collection and calculations yield the composite water footprint (WF = WFblue + WFgrey). The final phase involves sustainability evaluation and proposing measures for footprint reduction. Measurement outcomes indicate that the water footprint is highest in Scenario I, which involves direct wastewater discharge (7.479,507 m^3/month). In contrast, Scenario II with secondary treatment recorded a reduced footprint (3.628,295 m^3/month), while Scenario III, featuring tertiary treatment, exhibited the lowest footprint (2.062,718 m^3/month). These findings substantiate the critical role of wastewater treatment in minimizing the water footprint and underscore its necessity for promoting water resource sustainability. Also, the reuse of treated wastewater reduces the water footprint, and such water can be reused for the purpose of irrigation of agricultural and green areas as well as for industrial processes. The degree of processing conditions its subsequent use, which brings financial savings (Morera, 2019.).

Reuse of treated wastewater is the process of turning wastewater into water that can be reused for other purposes (table 5). Through the natural water cycle, the earth has recycled and reused water for millions of years. However, when water recycling is mentioned, it is generally thought of projects that use technology to speed up these natural processes. Wastewater treatment can be adapted to the water quality requirements for planned reuse. Treated wastewater can be used as irrigation water and requires less treatment than water used as drinking water. Treated wastewater can be used to irrigate gardens or agricultural areas and to fertilize ponds (Mara, 2004.).

Table 5. The main applications of purified wastewater in the world

Category of use	**Application**
Use in Cities	irrigation of public parks, sports facilities, private gardens, street cleaning, fire protection systems, car washing
Agriculture	fields, pastures, orchards, greenhouses, viticulture, aquaculture
Industry	Water for production, cooling water, rinsing water
Recreation	fishing, sailing, swimming, irrigation of playgrounds, production of artificial snow
Environmental Protection	filling of rivers and swamps, habitat of wild animals, forestry
Drinking Water	refilling of surface water courses, treatment to quality drinking water

Source: Alcalde Sanz and Manfred Gawlik, Water Reuse in Europe, 2014.

The highest number of wastewater recycling facilities are in Japan (>1800) and the USA (> 800), followed by Australia (> 450), Europe (> 200), the Mediterranean and the Middle East (>100), Latin America (>50) and Sub-Saharan Africa (>20) (Sanz and Gawlik, 2014.). Today, that number is likely much higher given the rapid advances in wastewater treatment technology that allow communities to reuse water for a variety of purposes.

However, wastewater contains a wide range of microbial, chemical, and physical pollutants that pose a risk to human health and the environment. The use of such water must not cause the transmission of diseases, so wastewater must be treated with appropriate procedures before its reuse. To reduce the risk to human health and the environment when reusing treated wastewater, an increasing number of countries have begun to introduce guidelines and regulations for the safe use of such water (Sanz and Gawlik, 2014.).

For water reuse in agriculture and aquaculture, the World Health Organization has established specific guidelines to support the application of Regulation 2020/741 on minimum requirements for water reuse (WHO, 2006.) that define acceptable microbiological limits for reused water. These guidelines in themselves do not represent a regulatory framework, but regulations and laws related to the use of treated wastewater are adopted according to them. It is important to note that these guidelines refer to municipal wastewater from municipal or other wastewater treatment plants, and the share of industrial wastewater in them is limited. The US Environmental Protection Agency (US EPA) regulates many aspects of wastewater treatment and drinking water quality, and most states have established some criteria or guidelines for the beneficial use of recycled water (US EPA, 1992.). Water that, after the first and second stage treatment, wants to be used again for some other needs must be further processed using membrane processes to the appropriate quality. Depending on the purpose of such water, possible disinfection is also necessary to protect against pathogens.

Membrane processes can be classified into several categories depending on the pore size of the membrane itself and depending on the pressure that needs to be applied for each process. These processes include reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF) and microfiltration (MF). Water that was treated in the second stage using conventional devices must first be treated by microfiltration and then by reverse osmosis, while the use of the MBR system achieves a better quality of water that can immediately be treated by reverse osmosis (Mijatović and Matošić, 2015.).

The primary disinfection methods for wastewater are chlorination, ozonation, and ultraviolet (UV) radiation exposure.

Chlorination is commonly used to control microbiological water pollution in wastewater treatment. Chlorine-based compounds like elemental chlorine, chlorine dioxide, and hypochlorite are employed for disinfection. Chlorine reacts with organic substances, microorganisms, and nitrogen compounds present in water. Effective disinfection typically requires a minimum contact time of 30 minutes, and a residual chlorine concentration of 0.1 to 0.5 mg/l in drinking water indicates successful disinfection (Mijatović and Matošić, 2015.).

Ozonation is considered an effective method for water disinfection due to its ability to inactivate viruses, oxidize organic substances, and remove odours and colour without altering the water's mineral composition. Ozone is generated by passing dry air through electrodes under high voltage. This process breaks down oxygen molecules into free radicals, which then react to form ozone (Mijatović and Matošić, 2015.).

UV disinfection is highly efficient against bacteria, viruses, and spores by causing photochemical damage to microorganism cells' DNA or RNA. Clear water is necessary for optimal UV penetration. UV disinfection employs quartz lamps with mercury vapor, emitting radiation between 200 and 295 nm to damage microorganism DNA or RNA. UV disinfection offers advantages like minimal chemical use, low energy consumption, no impact on water taste or odor, and rapid disinfection (20-30 s) (Mijatović and Matošić, 2015.).

3.8. Reuse of treated wastewater for irrigation

The reuse of treated wastewater has many advantages such as less discharge of wastewater into the environment, less consumption of drinking water and financial savings. Of course, there are also disadvantages, for example, the possibility of endangering human health and contamination of natural water resources. Disadvantages can be reduced by using membrane technologies, which are very popular in wastewater treatment, as well as in subsequent treatment for reuse. Membranes have a great advantage, that is, the ability to remove dissolved substances, organic compounds, compounds with nitrogen and phosphorus, and pathogens such as bacteria and viruses (Qadir et al., 2007.).

Treated wastewater are an important source of water to help and follow the high demand for irrigation in agriculture. Therefore, in recent years, the use of treated wastewater in agriculture has been of great importance in irrigation in several water-scarce countries. (Qadir et al., 2007.). The reuse of treated wastewater in irrigation provides a significant amount of water, this contributing to the preservation of clean water resources and reducing the impact on the environment associated with the discharge of wastewater (Agrafioti and Diamadopoulos, 2012.).

Treated wastewater has been used in agriculture for centuries in the areas of Berlin, London, Milan, and Paris (Australian Academy of Technological Sciences and Engineering (AATSE), 2004.). Vegetable production in Hanoi is irrigated from urban and suburban areas which account for about 80% of the area (Lai, 2000.). About 26% of Pakistan's total vegetable production is irrigated with wastewater (Ensink et al., 2004.). Ghana informally irrigates agricultural areas on about 11,500 ha with diluted wastewater from rivers (Keraita and Drechsel, 2004.). China, Mexico, and the United States of America are the countries with the highest amount of reused wastewater, while Qatar, Israel and Kuwait are at the top of the table of countries with the highest degree of reuse per capita. China ranks first in total water reuse and Qatar ranks first in per capita water reuse. Kuwait has a share of reused water in the total area of 2.2%, while the USA processes 7.6 million m^3/day for reuse (Fluence, 2017.).

Worldwide, 1 billion m^3 of water is currently treated and reused annually. The potential is much greater, but it depends on the economic profitability and the possibility of using such water and legal regulations. Sulaibiya is the world's largest water treatment plant for reuse using membrane technology (Figure 6.). It is located near Kuwait and processes 375,000 m^3/day. Such water is not suitable for drinking and is mixed with brackish water. The influent initially undergoes primary treatment, followed by biological treatment. The goal of biological treatment is to produce an effluent with biological oxygen consumption (BOD) and total suspended solids (TSS) values not exceeding 20 mg/L. Biological treatment is followed by ultrafiltration (UF) and reverse osmosis (RO), where the effluent becomes usable for reuse. The combination of the previously mentioned membranes (UF+RO) enables the removal of bacteria and pathogens and thus produces water of satisfactory quality for reuse (Fluence, 2017.).

Figure 6. Sulaibiya wastewater treatment plant.
Source: The State of Kuwait Ministry of Public Works Sanitary Sector, accessed 20thSeptember 2023.

For World Water Day in 2017, the UN addressed the topic of wastewater, which helped raise awareness for solving this global problem. According to the Sustainable Development Goals proposed by the UN in the 2017 Water Development World Report, governments are committed to halving the share of untreated wastewater and significantly increasing recycling and safe reuse by 2030 (International Water Association (IWA),2018.).

Today, about 80% of wastewater ends up in waterways without treatment, endangering human health and the environment. In addition to the previously mentioned report, the World Water Development Report from 2017 talks about wastewater as an alternative resource. This report presents the technical aspects of wastewater, laws related to and reuse of wastewater. In Europe, 71% of wastewater undergoes some degree of treatment, and in South America this share is only 20%. The global market for wastewater reuse in 2016 reached a profit of 12.2 billion dollars, this kind of information shows the great need for this kind of industry and benefits for the environment, economy, and climate change, which is the reason that reuse is approached very seriously in the European Union. The 2013 Water Reuse Report presents trends and the current situation in the industry (European Commission, 2013.).

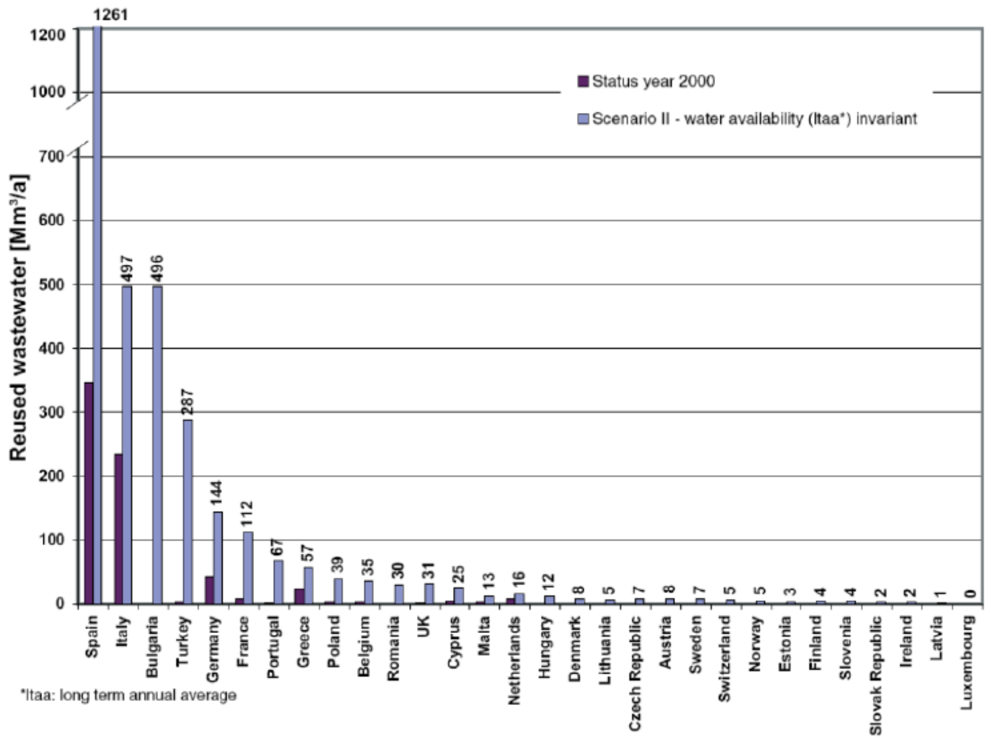


Figure 7. Model output for wastewater reuse potential of European countries with a projection horizon 2025.

Source: Global Report, Deloitte, 2014., accessed on 13th September 2023.

In some areas of Europe and the USA, wastewater is used on agricultural fields before wastewater treatment to prevent pollution of clean water resources (Asano, 2008.). In developing countries such as China, Mexico, Peru, Egypt, Lebanon, Morocco, India and Vietnam, wastewater has been used as a source of crop nutrients for many decades (Shuval et al., 1986.). However, major health risks but also the impact on the environment resulting from the use of wastewater for irrigation (Angelakis et al., 2003.). The main goal of water reuse for use in agriculture must be to ensure an adequate supply of high-quality water for agriculture and ensure food safety (Dobrowolski et al., 2008.).

In highly developed countries, there are integrated programs for planned reuse of wastewater for irrigation. California pioneered the treated wastewater irrigation program, the first regulations being published in 1918 (Asano and Levine, 1996.). In developed countries such as USA, Tunisia, Spain, France, Israel, and Jordan, use efficient treated and health-safe water before applying it to agricultural fields (Asano, 2008.).

Today, water treatment is an important aspect and addition to available water resources. Treated wastewater in Tunisia represented 4% of available water resources in 1996 and could reach 11% in 2030 (Qadir et al., 2007.). Highly developed countries have well-regulated and prescribed use of treated wastewater in irrigation (McCornick et al., 2004.). European Union for the planning and management of wastewater irrigation systems has had a prescribed Council directive (91/271/EEC) since 1991., according to these rules the use of treated municipal wastewater in agriculture can be an extremely significant good practice that can help ensure the safety and sustainability of food crops.

Water reuse in the EU is currently far from achieving its potential, even though the environmental impact and energy required to capture and distribute fresh water are much higher, and a third of the EU territory faces water supply problems throughout the year, and water scarcity remains an important issue for many EU member states. Increasingly unpredictable weather conditions, including severe droughts, are also likely to have negative consequences on the quantity and quality of freshwater resources. The new rules aim to ensure that the treated water from the municipal wastewater treatment plant is used in the best way possible and enabling a reliable alternative way of water supply. Utilizing non-potable wastewater as a new way of supplying water will contribute to financial savings and environmental benefits. The European Commission is putting accent on (EUC, 2013.):

- minimum requirements for water reuse, which include microbiological elements and requirements for routine and validation monitoring. Establishing minimum requirements will guarantee that treated water produced in accordance with the new rules is safe for irrigation.
- risk management, based on which all additional hazards must be removed so that the reuse of water is safe.
- increased transparency through which the public will have access to information on the practice of water reuse in their member state on the Internet.

Croatia is at the very top in terms of the amount of drinking water in Europe, but that does not justify the fact that the reuse of wastewater is minimal. In the Water Area Management Plan 2016-2021. adopted by the Government of the Republic of Croatia, reuse is mentioned only when preparing programs to encourage the implementation of water load reduction measures, in which the water reuse program (industry, agriculture, etc.) is also mentioned. The multi-year program for the construction of municipal water structures is a water management document prescribed by Article 37 of the Water Act (Croatian Official Gazette, no. 153/09, 130/11, 56/13, 14/14) and describes the framework program of project implementation, financing, personnel, and information resources as well as the sustainable use of water where, among other things, it mentions the reuse of wastewater for irrigation (Croatian Official Gazette, 107/95. and150/05.).

In the context of wastewater management in Croatia, is the establishment of the "water loop" system on Pag Island. Developed in collaboration with Tea Medicine, this fully biological wastewater treatment system caters to 5,000 users and has a daily capacity of 300-400 m³. The system repurposes UV-disinfected water for sanitation, resulting in significant annual savings (TEA Otpadne vode, 2014.).

3.9. Benefits of wastewater reuse, quality of wastewater and risk management

The overexploitation of water resources for agricultural, urban, and industrial activities can adversely impact water quality and biodiversity within ecosystems. Water treatment offers a dual advantage: reducing the strain on primary water sources and mitigating environmental wastewater discharge. Certain constituents of wastewater, such as nitrogen and phosphorus, can serve as alternative fertilizers in agriculture. Water reuse can also ameliorate environmental conditions in compromised aquatic habitats, fulfilling roles ranging from improving water quality to sustaining biodiversity, including in wetlands and fisheries. Thus, water recycling can be driven not just by supply needs but also by ecological imperatives (US EPA, 2020.).

As water demand increases, more water is extracted, treated, and sometimes transported over long distances, which can require a lot of energy. If the local water source is groundwater, the groundwater level decreases as more water is exploited and this increases the energy required to pump the water to the surface. Recycling water on-site or nearby reduces the energy needed to move water over long distances or pump water from aquifers. Adapting water quality to specific water uses also reduces the energy needed to treat water. The water quality required for toilet flushing is less strict requirements than the water quality required for drinking water and requires less energy to achieve. Using treated water of lower quality for uses that do not require high quality water, saves energy and money by reducing treatment requirements. Energy is first needed in the collection, extraction, transmission, and distribution of water to end users, and secondly in the treatment and disposal of wastewater after the end users have finished with it (European Commission, 2021.).

Although it requires additional energy to treat wastewater, the amount of energy required to treat and transport other water sources is generally much higher (European Commission, 2021.). The European Commission proposes to the EU member states the reuse of wastewater and adopts a proposal for a regulation on minimum requirements for water reuse, where the quality classes of treated water are defined, as well as the permitted uses and irrigation methods for each category and the minimum requirements for water quality (Table 6., Table 7.) (European Commission, 2020.).

Table 6. Classes of treated water quality and permitted agricultural use and irrigation method.

Minimum treated water quality class	Crop category (*)	Irrigation method
A	All food crops consumed raw where the edible part is in direct contact with reclaimed water and root crops consumed raw	All irrigation methods
B	Food crops consumed raw where the edible part is produced above ground and is not in direct contact with reclaimed water, processed food crops and non-food crops including crops used to feed milk- or meat-producing animals	All irrigation methods
C	Food crops consumed raw where the edible part is produced above ground and is not in direct contact with reclaimed water, processed food crops and non-food crops including crops used to feed milk- or meat-producing animals	Drip irrigation (**) or other irrigation method that avoids direct contact with the edible part of the crop
D	Industrial, energy and seeded crops	All irrigation methods (***)

(*) If the same type of irrigated crop falls under multiple categories of *Table 6.*, the requirements of the most stringent category shall apply.

(**) Drip irrigation (also called trickle irrigation) is a micro-irrigation system capable of delivering water drops or tiny streams to the plants and involves dripping water onto the soil or directly under its surface at very low rates (2–20 litres/hour) from a system of small-diameter plastic pipes fitted with outlets called emitters or drippers.

(***) In the case of irrigation methods which imitate rain, special attention should be paid to the protection of the health of workers or bystanders. For this purpose, appropriate preventive measures shall be applied.

Source: Regulation EU, 2020/741 of the European Parliament and of the Council, 2020.

Table 7. Treated water quality requirements for agricultural irrigation.

Treated water quality class	Indicative technology target	E. coli (number/100 ml)	BOD5 (mg/l)	TSS (mg/l)	Turbidity (NTU)	Other
A	Secondary treatment, filtration, and disinfection	≤ 10	≤ 10	≤ 10	≤ 5	*Legionella* spp.: < 1 000 cfu/l where there is a risk of aerosolization Intestinal nematodes (helminth eggs): ≤ 1 egg/l for irrigation of pastures or forage
B	Secondary treatment, filtration, and disinfection	≤ 100	Directive In accordance with 91/271/EEC (Annex I, Table 6)	Directive In accordance with 91/271/EEC (Annex I, Table 6)	-	*Legionella* spp.: < 1 000 cfu/l where there is a risk of aerosolization Intestinal nematodes (helminth eggs): ≤ 1 egg/l for irrigation of pastures or forage
C	Secondary treatment, filtration, and disinfection	≤ 1000			-	
D	Secondary treatment, filtration, and disinfection	≤ 10000			-	

Source: Regulation EU, 2020/741 of the European Parliament and of the Council, 2020.

The potential for municipal wastewater reuse extends beyond agricultural applications to include city maintenance activities such as irrigation of public green spaces, street cleaning, fire protection, and water fountains. Such urban applications necessitate third stage water treatment to meet quality standards. However, the distribution of treated wastewater remains a challenge, requiring separate infrastructure and offering primarily seasonal benefits, particularly during dry summer months. Despite these obstacles, the financial advantages of wastewater reuse in mitigating water supply costs are noteworthy, especially in the agricultural sector. However, the implementation of water reuse systems mandates a thorough risk assessment, accounting for both human and environmental health considerations. According to European Regulation (European Commission,2020/741), a comprehensive system description encompassing wastewater sources, treatment stages, supply infrastructure, and points of use is obligatory. Risk assessments are divided into environmental and human health categories. Environmental risk assessment involves hazard identification, exposure range assessment, and risk characterization. Correspondingly, human health risk assessment includes hazard characterization, dose-response relationships, exposure range evaluation, and risk characterization (EU Parliament, 2020.).

3.10. Issues of using wastewater and impact on the environment

The industry development, demographic growth, and economic development lead to an increase in the consumption of water resources, and the problem of creating quantities of wastewater also arises. Wastewater can contain a wide range of pollutants such as coarse residues, microorganisms, dispersed and dissolved substances, nutrient salts, and dissolved gases. An example of a flow of potential pathogen transmission (Figure 8.). The wastewater treatment process is important for the protection of the environment and human health so that treated wastewater can be reused or released into the environment (Tchobanoglous et al., 2003.).

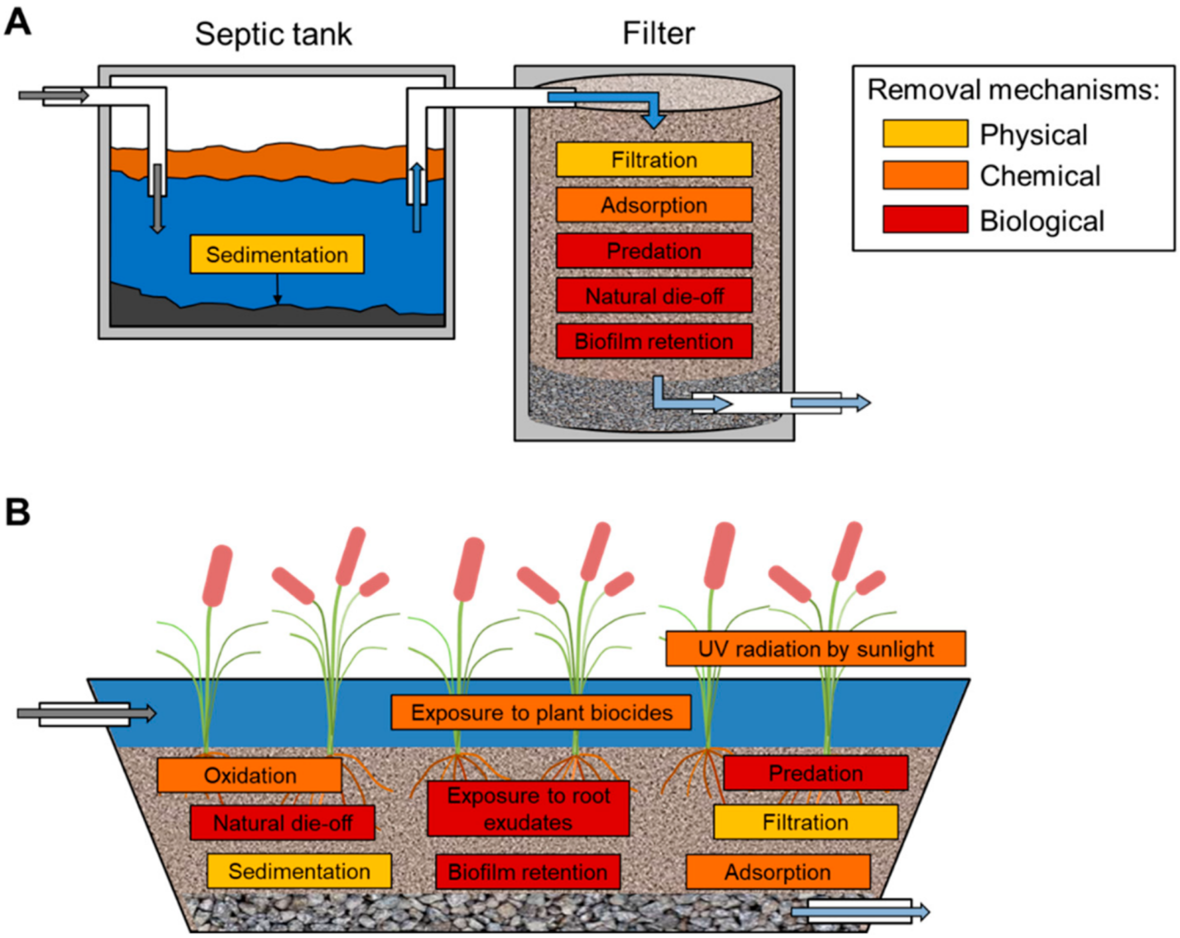


Figure 8. The removal mechanisms of pathogens.
(A): Major pathogen removal mechanisms involved in a conventional septic tank and sand filtration system.
(B): Major pathogen removal mechanisms involved in a constructed wetland.
Source: Removal of Pathogens in Onsite Wastewater Treatment Systems, 2021., accessed 10th September 2023.

The reuse of wastewater in agriculture requires an integrated approach and planning of the entire system, considering economic, ecological and health risk factors. The development of wastewater reuse has great potential for future use. However, the concept of wastewater remediation requires a project plan for public health protection, environmental pollution control, and water resource management. Most aspects still need to be studied in more detail, since they require the development of appropriate strategies and qualified bodies for local management of treatment and reuse projects of wastewater. A key issue is often the lack of institutional setting and guidelines or measures to implement planned reuse. Also, the regulatory settings of the directives can be a tool that helps in public acceptance and willingness to implement reuse projects (Tchobanoglous et al., 2003.).

Water is essential for life, and it takes about 70 % of the Earth's surface area, and in fact only a small part of water is compatible with terrestrial life forms (Shiklomanov, 1993.). A small proportion of fresh water is available (2.5% of the total water supply in the hydrosphere), mainly in the form of trapped ice and permanent snow covers in the Antarctic and Arctic regions (68.7%) (Shiklomanov, 1993.). The lack of water leads to the consequence that 40% of the total land area is dry and includes climatic zones classified as arid and semi-arid climates (FAO, 2008.). The problem today is the increasing need for water resources due to demographic growth, economic development and improvement of living standards, climate change and pollution (FAO, 2012.). It is estimated that in at least some regions of the world, water use is growing at more than twice the rate of human population. Reductions in the use and pumping of freshwater, using wastewater will also contribute to and reduce the discharge of wastewater into freshwater ecosystems (Bixio et al., 2006., Toze, 2006.).

It is precisely in this scenario that wastewater becomes an increasingly valuable resource, and not just a waste product. However, despite the mentioned advantages, the reuse of wastewater also involves health and environmental risks. Environmental protection guidelines have as a priority to prevent potential effects on soil productivity, fertility, and to prevent disorders of the physicochemical properties of the soil and reduce risks to human health due to the presence of toxic compounds and pathogens (Aquarec, 2006.; EPA, 2012.; WHO, 2006.). However, the impact of wastewater irrigation on soil ecosystem services, which rely on an appropriate balance of soil microorganism diversity and activity, is crucial for soil health (Anderson, 2003.; Torsvik and Ovreas, 2002.). Parameters affecting the sustainable and safe reuse of wastewater and soil health and safety should be included in quality standards, avoiding disturbance of soil properties and the spread of new chemical and biological pollutants. Technological solutions with negligible impacts on the environment are important, and it is necessary to ensure the concept of wastewater treatment with sustainable use. The primary task of wastewater treatment is determined by environmental protection plans (Margeta, 2007.).

Public acceptance of treated wastewater for agricultural irrigation is multifaceted, influenced by various factors. Key considerations include safety concerns related to pathogens, chemicals, and heavy metals, necessitating rigorous treatment and quality standards (EPA Guidelines for Wastewater Reuse, 2020). Awareness and education play a vital role, informed communities are more likely to embrace water reuse practices. Educational campaigns and transparent communication are essential (EU Commission, 2019). Water scarcity amplifies acceptance, especially in drought-prone regions where wastewater can be a more sustainable water source (FAO Water Scarcity Atlas, 2018). Robust regulations and oversight, defined by comprehensive guidelines and water quality monitoring, bolster confidence in wastewater reuse (WHO, 2017). Cultural practices impact acceptance, with historical traditions can enhance willingness (Dahlin, 2021). Successful demonstration initiatives showcasing improved crop yields and reduced freshwater pressure boost support (Water Research Foundation, 2019). Environmental benefits like ecosystem conservation and pollution mitigation can sway opinions (Environmental Science & Technology, 2020). Lastly, community engagement and involvement in decision-making processes foster acceptance and consensus (Water Policy, 2017).

Conducting a survey on wastewater requires several steps to comprehensively grasp public sentiments, attitudes, and concerns related to this specific aspect of environmental sustainability. Here are key considerations for undertaking such a survey (Taherdoost, 2022.):

- Establish Clear Objectives
- Craft an Inclusive Questionnaire
- Deliberate on Target Audience
- Ethical Contemplation
- Preliminary Testing
- Sampling Strategy
- Data Collection Medium.
- Data Analysis
- Presentation and Dissemination
- Practical Recommendations
- Stakeholder Engagement
- Ongoing Monitoring

Within the agricultural sustainability and regional development, the management of water resources assumes prime importance. This significance is pronounced in regions like Istria County, where agriculture holds an important role in the local economy. This coastal county known for its tourism, witnesses a substantial population surge during the summer season. This dual role as an agricultural hub and a tourist hotspot place demands on the county's precious water resources. The initiation of a survey cantered on wastewater management and reuse becomes a concern for the region's sustainable development.

4. Materials and Methods

4.1. The research area

The research presented in this thesis was undertaken within Istria County, a region situated in the westernmost part of Croatia. Istria, characterized by its Mediterranean climate and diverse topography, plays a pivotal role in Croatia's agricultural and tourism sectors. The county's agricultural landscape is marked by olive groves, vineyards, and truffle forests, making it a significant contributor to the nation's agronomic output. Concurrently, as a leading tourist destination, Istria faces the dual challenge of balancing sustainable tourism with agricultural productivity. For the evaluation of wastewater, three wastewater treatment plants (WTP) in Istria County were selected, ensuring they represent facilities of varying capacities: 1) WTP, 2) WTP Sveti Lovreč and 3) WTP Kanfanar.

The County of Roč is in the center of northern Istria, at 348 m above sea level. The place is located at the junction of limestone, from which Ćićarija and Učka were built, and marl, which are the valleys and ridges below those two mountains.

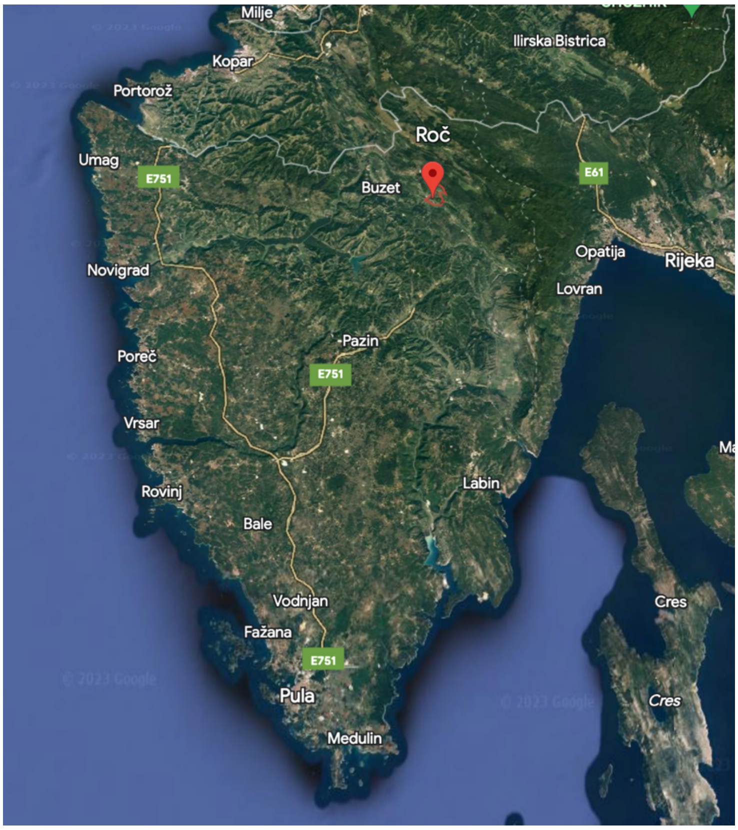


Figure 9. Satellite view of the peninsula of Istria, and position of Roč

Source: Google Earth, 2023., accessed 22nd September 2023.

The collector network of the Roč system includes settlements: Roč, station Roč, Grgurinčići, Kolinasi, Bršćak, Rim. The length of the pipelines through which the sanitary wastewater of these settlements is collected is a total of 7,165 meters, with one pumping station in Roč.

Wastewater treatment plant is of the MBR (membrane bioreactor) type with a load capacity of 500 + 500 population equivalent (PE) in the final phase of operation. The membrane bioreactor is a biological treatment system for wastewater treatment, improved by the addition of ultrafiltration, which achieves the maximum treatment effect (>98%) and the optimal quality of treated wastewater for discharge into a sensitive area. Roč is in the II zone of sanitary protection of the source of drinking water Sveti Ivan, and the wastewater treatment plant itself is in the III zone in the village of Rim (Istarski vodovod buzet, (IVB), 2023.).

In the first phase, the plant system was constructed for the final capacity, and it was equipped with hydromechanical equipment only for the first phase of 500 PE. The system was in trial operation during 2013-14. when the guaranteed parameters for its safe operation were proven, and since the beginning of 2015, the wastewater treatment plant has been in regular operation. The second phase of the wastewater treatment plant, the deadline for an additional 500 PE was equipped during 2019. and simultaneously with the connection of consumers to the new sewage system of the Ročko Polje settlement, the trial operation of the new wastewater treatment line begins, which now has a full capacity of 1000 PE (Istarski vodovod Buzet, (IVB), 2023.).

Sveti Lovreč is located at 45°11' north latitude, 13°45' east longitude and 202 meters above sea level. It is located on a hill, next to the state road Pula-Buje.

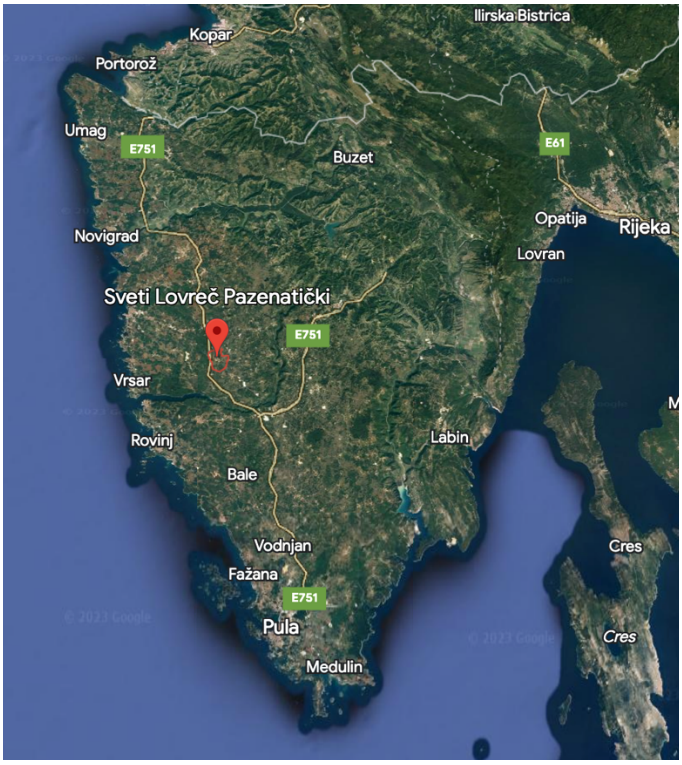


Figure 10. Satellite view of the peninsula of Istria, and position of Lovreč.

Source: Google Earth, 2023. Accessed 23rd September 2023.

The sewage system of the municipality of Poreč, which includes Lovreč, is organized and dimensioned according to the needs of the tourist industry and citizens of Poreč during the peak tourist season and according to the technological standards valid for the middle of the second half of the last century (mechanical wastewater treatment with a long sub-marine outlet). By investing in wastewater treatment facilities, Usluga Poreč d.o.o. wants to achieve the standards required by the EU and the quality of the coastal sea for swimming and to build sewage systems for settlements in the hinterland of the coast. The existing systems were dimensioned for the needs of the population, approximately 15,000 inhabitants and 100,000 tourists. They were created because of the high ecological awareness of businessmen and local self-government, but in accordance with the environmental standards of the time. And because of this, the City of Poreč, according to the accepted concept, is starting to implement the Jadran project (the entire project is shown under "Development projects" in the main menu). In August 2007, a device for the reception and treatment of wastewater from the "Košambra" septic tanks was put into operation. The contents of septic tanks are emptied every working day, in accordance with citizens' requests. The device has a designed daily capacity of 240 m³, which increases to 360 m³ in the summer. In the same year, the wastewater drainage concept was accepted, which is based on 4 independent drainage systems, made by the company Eko Mlaz from Novska. This conception accepts III. degree of water purification at the locations of existing devices. In August 2008, a wastewater treatment plant was built in Sveti Lovreč. It is a membrane device for 2 x 200 PE that contains mechanical purification, biological purification, and purification of wastewater from bacteria, which enables the reuse of water. The device is modern, with minimal waste, because the purified water can be used for watering parks, playgrounds, agricultural areas, and the remaining sludge is compacted, treated, and used as compost (Usluga Poreč d.o.o., 2023.).

Kanfanar, situated at the heart of Istria County, attained municipality status in 1993, previously falling under the administrative jurisdiction of Rovinj. Nestled at an elevation of 284 meters above sea level, Kanfanar spans an expanse of 60 square kilometres. Its boundaries connect with neighbouring municipalities and cities, including Rovinj, Bale, Svetvinčenat, Žminj, Sveti Lovreč, Vrsar, and Tinjan. Additionally, it enjoys access to the Adriatic Sea via the Lim Fjord.

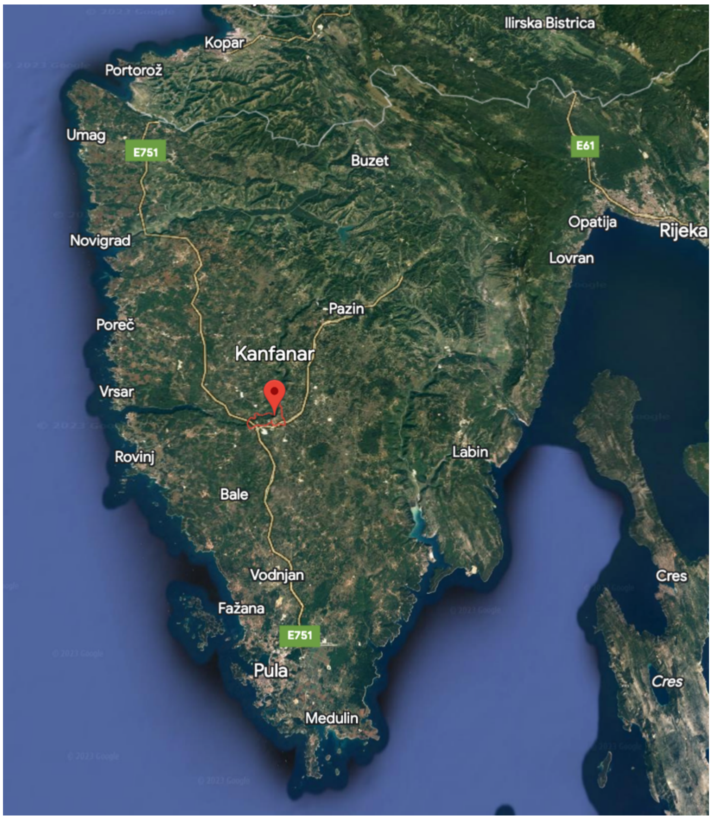


Figure 11. Satellite view of the peninsula of Istria, and position of Kanfanar.

Source: Google Earth, 2023., accessed 23rd September 2023.

The wastewater treatment plant in Kanfanar, which was built in 2006 by the contractor Limska Draga d.o.o., was originally intended to accommodate a load of 2,000 PE during its initial operational phase. However, in its second phase of operation, it has consistently managed an average load of 5,000 PE, with peak loads occasionally reaching as high as 6,500 PE (Limska Draga d.o.o. 2023.).

4.2. Treated wastewater analysis

Wastewater sampling in treatment facilities is a critical practice for assessing water quality, regulatory compliance, and potential irrigation applications. A comprehensive approach involves stringent safety measures, including the use of personal protective equipment, as outlined in EPA Guidelines (2004.) and European Union regulations (Regulation EU, 2020.). Proper preparation of sampling equipment, such as clean and sterilized containers, in compliance with ASTM International (2019.), is essential. Selection of sampling locations at different treatment stages (influent, primary, secondary, effluent) follows established protocols like the EPA Guidelines (2004.). Two fundamental sampling techniques are instantaneous and composite, each serving specific purposes (WHO Guidelines for Drinking-water Quality, 2023.). Adherence to precise collection methods and preservation, including pH adjustments and temperature control, aligns with (ISO 5667-3:2018) standards. Transportation and documentation, ensuring sample integrity and compliance with regulations, are guided by the WHO Water Safety Plan Manual (2013.). Laboratory analysis and reporting, conducted according to recognized procedures and standards (Ginley and Kleinprovide, 2017.) accurate and reliable data. Rigorous record-keeping, following established procedures and templates, documents the entire sampling process, analytical results, and subsequent actions (EPA Guidelines, 2019.).

Sampling was carried out at three locations in the County of Istria - Lovreč, Kanfanar and Roč - on three different dates (30th May, 13th June and 2nd July) in 2018. The collected samples were analysed for essential parameters, including pH, electrical conductivity (E.C./ 25°C), calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+), sodium (Na+) and bicarbonate ($HCO3^-$). Internationally recognized protocols and standards for sample collection and analysis were followed (EPA, 2020; ASTM, 2019; WHO, 2017.).

Table 8. Treated wastewater analysis, samples taken on 30th May 2018.

WTP	pH	E.C./ 25°C	Ca^{2+}	Mg^{2+}	K^+	Na^+	HCO_3^-
	25°C	dS / m	mg / L				
KANFANAR	7,8	0,436	80	13	1,1	6,6	265
ROČ	7,7	1,41	96	6,8	27	91	671
SV.LOVREČ	7,4	1,13	83	16	29	139	412

Source: Faculty of Agriculture Zagreb, 2018.

Table 9. Treated wastewater analysis, samples taken on 13th June 2018.

WTP	pH	E.C./ 25°C	Ca^{2+}	Mg^{2+}	K^+	Na^+	HCO_3^-
Treatment facilities	25°C	dS / m	mg / L				
KANFANAR	7,6	0,810	80	9,7	24	72	336
ROČ	7,3	1,10	112	5,8	26	87	146
SV.LOVREČ	7,7	1,08	80	12	25	129	329

Source: Faculty of Agriculture Zagreb, 2018.

Table 10. Treated wastewater analysis, samples taken on 2nd July 2018.

WTP Treatment facilities	pH 25°C	E.C./ 25°C dS / m	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	HCO_3^{-}
			mg / L				
KANFANAR	7,9	1,18	75	13	33	115	476
SV.LOVREČ	7,7	1,27	104	9,7	31	124	183

Source: Faculty of Agriculture Zagreb, 2018.

Analysis of treated wastewater samples from three locations and different dates yielded different findings:

- pH: The pH levels ranged from 7.3 to 7.9, indicating a slightly alkaline nature, generally suitable for irrigation.
- Electrical conductivity (E.C./ 25°C): E.C. values ranged from 0.436 to 1.41 dS/m, indicating variations in solute concentrations.
- Calcium (Ca^{2+}) and magnesium (Mg^{2+}): Ca^{2+} and Mg^{2+} concentrations showed variability, potentially affecting soil quality and crop health.
- Potassium (K^{+}) and sodium (Na^{+}): K^{+} and Na^{+} levels showed differences, with possible implications for crop nutrition and soil salinity.
- Bicarbonate ($HCO3^{-}$): $HCO3^{-}$ levels varied, affecting water alkalinity and potential crop growth.

4.3. Survey

To initiate the study of wastewater management in Istria County, this research employed a Google Form survey to engage a diverse group of stakeholders, including agricultural producers, local officials, and esteemed academics (Attachment 9.1.). Anonymity and GDPR compliance were ensured. The choice of the Google Form platform was deliberate, its intuitive interface made it possible to create a questionnaire that was easy to use and versatile. Respondents were able to access and complete the survey, which was posted online (https://forms.gle/gBKJeMyhvzWKyihd6). The platform enabled the collection of responses in real time, making it a dynamic and effective data collection tool (*Figure 12.*).

To ensure broad participation and reach, the survey was distributed via email to targeted recipients. Agricultural producers, as those directly affected by wastewater management practices, received invitations. Municipal leaders, well versed in local policies and challenges, were also involved in outreach. Scientists specializing in agriculture and wastewater treatment have been engaged to provide their expertise.

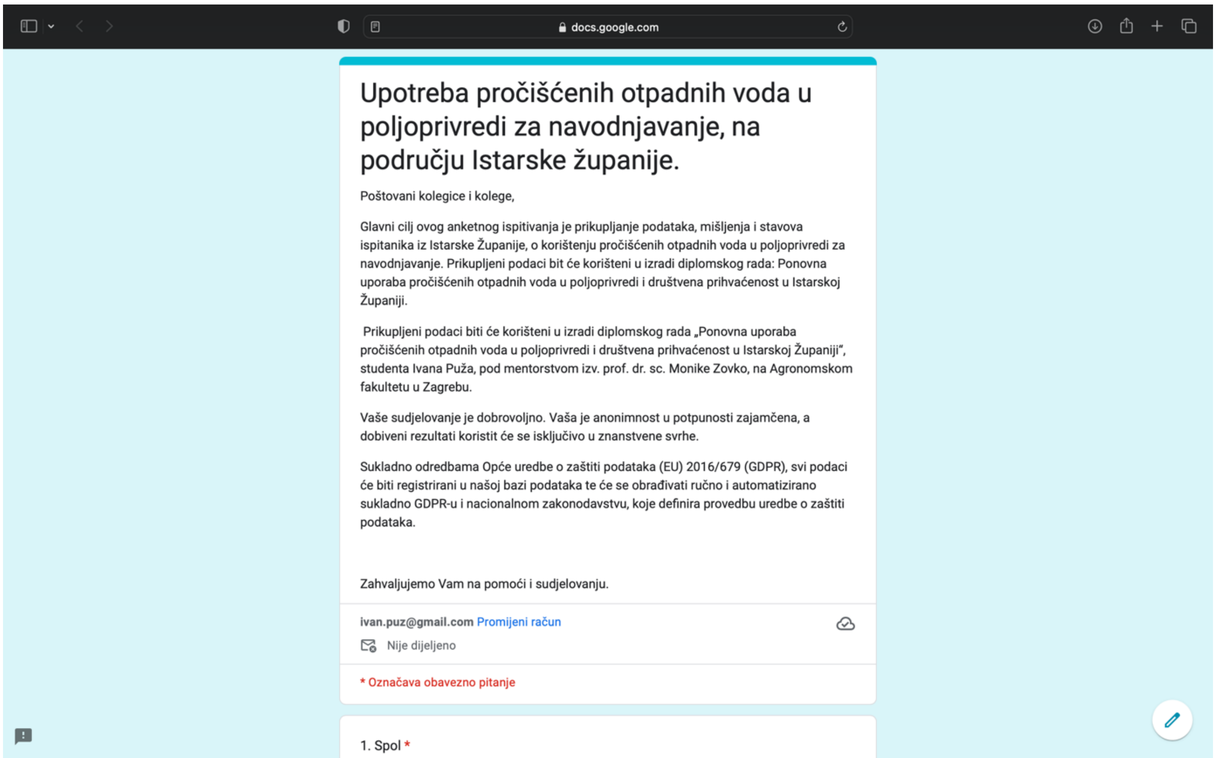


Figure 12. Introduction of the survey conducted in Croatian on Google Forms.

The survey covered a set of 24 questions, and an open-ended section designed to encourage respondents to provide unrestricted written insights regarding the topic of wastewater reuse in agriculture, specifically for irrigation purposes. The questionnaire primarily sought after a basic demographic information from the participants, encompassing their respective backgrounds, age, levels of education, general awareness levels which refers to wastewater reuse, occupational classifications, landholding sizes, and whether they engage in agricultural irrigation practices.

Furthermore, the survey delved into the details of respondent's irrigation practices, comprehensive inquiries about the specific types of irrigation systems they employ, the primary sources of water they access for their irrigation needs, and their perspectives on water restrictions that may be imposed during the summer months.

Moreover, the survey explored respondent's receptivity to acquiring knowledge about the utilization of treated wastewater for irrigation, thus shedding light on their willingness to embrace innovative agricultural practices.

Lastly, the survey probed into respondent's concerns and reservations surrounding the use of treated wastewater in agricultural contexts, aiming to uncover any apprehensions or reservations that might influence their willingness to adopt this sustainable approach to irrigation. The survey aim is to construct a short overview of respondents' perspectives, knowledge levels, and acceptance regarding wastewater reuse in agricultural irrigation, thereby facilitating an analysis of the collected data.

5. Results

5.1. Survey results

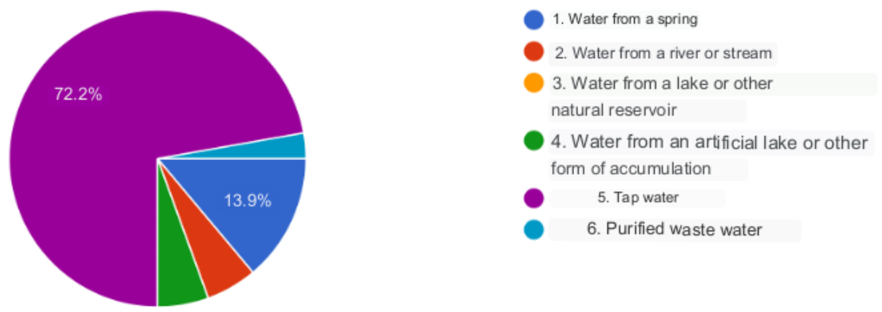
The survey was distributed electronically via e-mail to various stakeholders in the County of Istria. These stakeholders included non-governmental organizations (NGOs), head of municipalities and agricultural producers. Electronic distribution enabled efficient and convenient data collection while ensuring the widest possible participation of these key groups. The survey was sent at 120 emails, to cover the area of Istria County, sent the first time at 26th of May 2023., and the second time 15th of September 2023. The survey results received a total of 36 acceptable answers. The survey's results (Attachment 9.2.) reflect a well-balanced and diverse participation, with 61,1% female and 38,9% male respondents. Notably, 30,6% of participants fell within the 46 to 55 years age group, 25% were between 36 to 45 years, 22,2% were from 26 to 35 years of age, 13,9% were from the group of age 56 to 65 and lastly 8,3% from 18 – to 25 years of age.

58,3% possessed master's degrees or higher education, indicating a highly educated and experienced group, 25% have completed 4-year high school, 11,1% have completed 3-year high school and 5,6% have bachelor's degree, engaging in discussions about treated wastewater reuse in agriculture. Among the respondents, 30,6% identified as agricultural producers, while 52,8% were municipal officials, 22,2% were entrepreneurs in the County of Istria.

In the subsequent section of the survey, participants were asked to provide insights into the nature of their businesses. The results revealed that beside their occupation they have their own family agricultural businesses comprising 63,9% of respondents, a minority of worked at limited liability company (Ltd) 13,9%. Additionally, when examining the land area that the respondent own, a 33,3% indicated that their land holdings were not larger than 1 hectare, 19,4% have a land area of 4 to 9,9 hectares, 16,7% have a land area of 1 to 1,9 hectares, and an 8,3% of respondent have an area of 2 to 3,9 hectares, and the same from 10 – 19,9 hectares. Furthermore, the survey delved into the practice of irrigation, revealing that more than half of the of respondents confirmed that they don't use an irrigation system on their land, 30,6% of agricultural producers, 27,3% of them use irrigation practices on their agricultural family businesses.

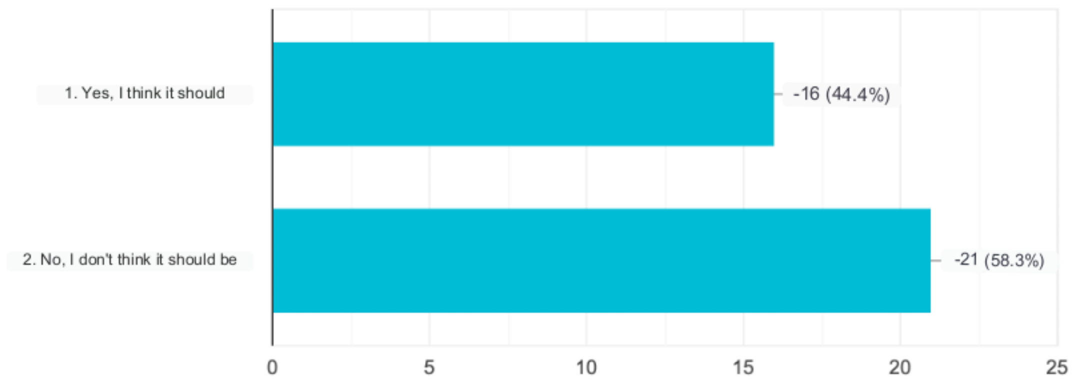
Another result from the survey is that 69,4% suggested the importance of water in their agricultural activities. This underscores the importance of water resources to their businesses, highlighting its role in crop cultivation, livestock maintenance, and overall agricultural sustainability within Istria County, and 44,4% of respondents that are practicing the use of irrigation systems, are utilizing drip irrigation a water-efficient technique in their agricultural practices or on their family agricultural businesses.

Q 12: From which source you use water for irrigation?

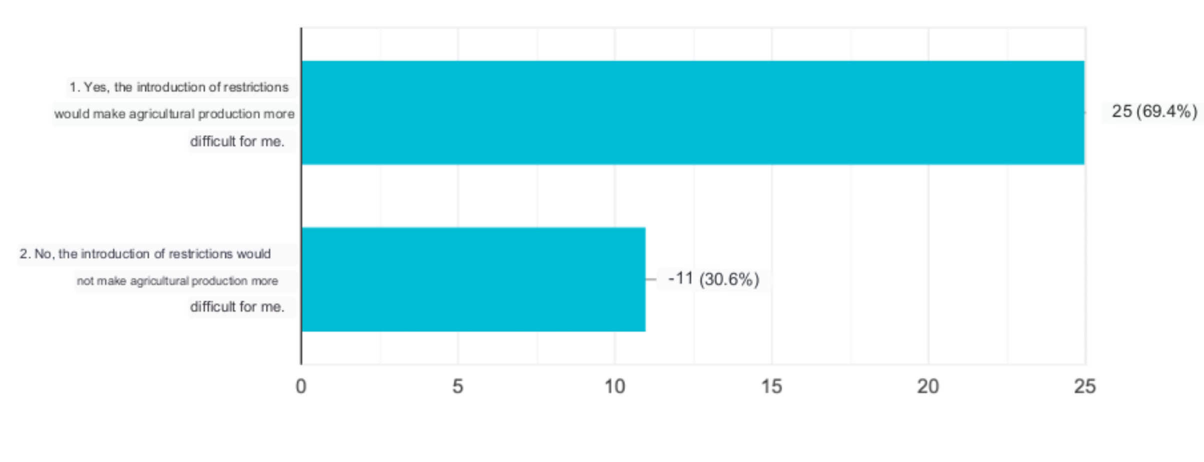


The survey results for question number 12, show that a 71.4% of respondents rely on water supply system for their irrigation needs. This preference for water supply as an irrigation source highlights the convenience and accessibility of municipal water supplies for agricultural purposes in Istria County. It also underlines the need for sustainable water management practices, given the dependence of agricultural operations on this essential resource. Understanding the prevalent use of water from the water supply systems provides knowledge for policymakers and stakeholders aiming to ensure the long-term viability of agriculture in the region while maintaining responsible water usage.

Q13: Do you think that restrictions should be introduced for the use of water in the summer period?



Q14: Would the introduction of water restrictions make agricultural production more difficult for you?



The results show that 58,3% of respondents do not support the introduction of water use restrictions during the summer period, highlighting a preference for maintaining flexibility in water usage for agricultural needs in Istria County, but 69,4% consider that with the introduction of the water restrictions during the summer period will affect their business, suggesting that there is a strong apprehension among many respondents regarding the potential consequences of water use restrictions during the crucial summer months for their livelihoods and agricultural sustainability.

Among the survey results, it is apparent that 75% of respondents have been exposed to the concept of utilizing treated wastewater for agricultural irrigation, signifying a reasonably high level of awareness within the community. Nonetheless, 75% of participants expressed a lack of supplementary information or comprehensive knowledge regarding the reuse of treated wastewater in agriculture for irrigation. Moreover, the majority of respondents 72,2% indicated uncertainty regarding whether community members currently employ treated wastewater for agricultural irrigation. This prevailing uncertainty suggests a potential void in communication and awareness within the community regarding the actual uptake of treated wastewater reuse practices.

A significant portion of survey respondents 55,6% are willing to acquire more information about treated wastewater and its potential applications in agriculture. From the survey, it is evident that they perceive treated wastewater as a viable and beneficial solution. Interestingly, despite this positive outlook, 33 respondents of 36 or 91,7% of the respondents currently do not incorporate treated wastewater into their business operations. However, they indicated a keen interest in having the option to use treated wastewater for irrigation, particularly during periods of water restrictions in the summer months.

The issue emphasized by survey participants pertains to the quality of treated wastewater, 38,9% are concerned about the treated wastewater safety and 30,6% didn't express their position as they are not sure. The respondent demonstrates a significant interest in acquiring knowledge, into treated wastewater quality and water analysis procedures 55,6% is willing to acquire more information. Furthermore, the respondents 80,6% confirm their readiness to utilize treated wastewater for irrigation, depending upon the provision of comprehensive information that attests to its safety.

In the final section of the survey, participants were given the opportunity to provide open-ended feedback, almost everybody left their private note and comment about treated wastewater and utilisation in agriculture. The predominant sentiment expressed was one of positivity and encouragement regarding treated wastewater reuse in agriculture. However, a common thread running through these responses was the perceived lack of information about treated wastewater and its untapped potential. Concerns were also voiced regarding the cost associated with delivering the treated water to the end consumer, primarily the agricultural producer, as well as concerns related to infrastructure limitations, water quality and the safety concern.

6. Discussion

The research aimed to identify the social acceptance, and the reuse of treated wastewater in agriculture for irrigation within the Istria County. The results reveal insights from a diverse group of stakeholders, including NGOs, agricultural producers, scientists, and officials. The survey served as an instrument in gauging social acceptance and understanding within the community.

The survey results underline the positive inclination of a portion of the surveyed population towards the potential utilization of treated wastewater in agriculture. This inclination is particularly notable among respondents who are keen to obtain more information about treated wastewater and its possible applications in agricultural practices. However, a concern that emerged from the survey is the lack of information regarding treated wastewater. A substantial percentage of respondents expressed a need for more comprehensive knowledge about water quality and water analysis, showing that informed decision-making depends on transparent and accessible information. This knowledge deficit represents an opportunity for educational initiatives to bridge the gap and facilitate greater awareness and understanding. Furthermore, the survey revealed apprehensions related to the cost associated with delivering treated wastewater to end consumers, primarily agricultural producers. This concern aligns with practical considerations of infrastructure development and maintenance. Addressing these cost-related issues will be critical in realizing the full potential of treated wastewater reuse for irrigation.

Despite these challenges, there is a clear consensus among respondents that having access to safe and treated wastewater for irrigation during periods of water scarcity, such as the summer months, is highly desirable. This reflects the recognition of the benefits of responsible water management practices, not only in supporting agricultural productivity but also in safeguarding the environment and ensuring long-term sustainability.

The European Commission's Water Framework Directive underpins the principles of integrated water resource management, emphasizing the need for sustainable water use and protection. The survey results reflect a growing awareness among stakeholders regarding the potential of treated wastewater in addressing water scarcity issues, aligning with the directive's emphasis on sustainable practices. The European Environment Agency's report on water management in Europe highlights the significance of both price and non-price approaches to water conservation. The survey responses indicate that stakeholders are sensitive to the concept of treated wastewater reuse, which can contribute to water conservation and sustainable water management practices in line with the report's recommendations. Council Directive (91/676/EEC) concerning the protection of waters against pollution caused by nitrates from agricultural sources underscores the need to mitigate agricultural impacts on water quality.

The survey results, coupled with water analysis results, emphasize the importance of responsible agricultural practices and the potential role of treated wastewater in reducing agricultural pollution, aligning with the directive's objectives.

The European Commission's 2021 report on the implementation of Directive (91/676/EEC) further underscores the relevance of addressing nitrate pollution from agricultural sources. The survey's focus on stakeholder opinions and their willingness to use treated wastewater for irrigation demonstrates a collective readiness to explore solutions that can contribute to meeting the directive's goals. Additionally, academic research such as the study by Romić et al. (2014.) on the impact of agriculture on water pollution in Croatia provides insights into the link between agriculture and water quality. The survey responses corroborate the need for sustainable agricultural practices to mitigate pollution, with treated wastewater offering a potential solution.

The survey outcomes offer a view of the collective perspectives of various stakeholders, including NGOs, agricultural producers, scientists, and municipal officials, concerning the possible utilization of treated wastewater for agricultural irrigation within Istria County. Demographically, the survey reflects a balanced gender distribution, demonstrating a diverse representation of respondents spanning various age groups. Educationally, the respondent pool is characterized by a high level of educational attainment, with many respondents holding advanced degrees.

Occupationally, the survey encompasses a broad spectrum, featuring agricultural producers and municipal officials. This diversity of participants ensures a varied perspective, encompassing those directly engaged in agricultural activities and those responsible for local governance. Regarding respondent's businesses, a significant proportion are engaged in family-based agricultural enterprises, indicative of the sector's familial and traditional roots in the region. Concerning irrigation practices, drip irrigation emerges as a favoured method, showcasing an inclination toward water-efficient techniques. The predominant source of irrigation water is drinking water from water supply, reflecting conventional water sourcing methods. The survey also delves into viewpoints on potential summertime water restrictions. A substantial portion of respondents advocates against their introduction, signalling a preference for unrestricted access to water resources. However, concerns about the adverse impacts of such restrictions on businesses are widespread, underscoring the interplay between water resource management and economic viability in agriculture. Regarding awareness of treated wastewater reuse, most respondents indicate familiarity with the concept, suggesting a growing recognition of its sustainability. Nonetheless, there exists a notable gap in additional knowledge, emphasizing the necessity for enhanced education and outreach efforts. In summary, the survey findings provide knowledge into perspectives, practices, and apprehensions of Istria County's stakeholders regarding the potential adoption of treated wastewater for agricultural irrigation. These insights form the basis for informed decision-making and policy development, facilitating the advancement of more sustainable and resilient agricultural practices in the region.

In conclusion, the survey, with its diverse group of respondents, sheds light on the social acceptance and perceptions surrounding the reuse of treated wastewater in agriculture for irrigation in Istria County. While there is enthusiasm for this sustainable practice, it is imperative to address the information gap, cost concerns, and infrastructure considerations to facilitate its successful implementation. With the right education, awareness, and infrastructure support, treated wastewater reuse can be a transformative solution with far-reaching benefits for agriculture and the environment in Istria County.

7. Conclusion

This thesis encompasses several key objectives focused on the utilization of treated wastewater for agricultural purposes. Firstly, it provides an examination of the multifaceted issues and advantages associated with wastewater reuse (WWR), offering a comprehensive overview of its potential for promoting sustainable agricultural practices. The study conducts an evaluation of the European Union's strategic framework and guidelines governing the safe implementation of WWR in agriculture, ensuring adherence to international standards and the promotion of responsible practices. Additionally, it conducts a feasibility analysis of WWR for irrigation, utilizing available water quality data from wastewater treatment facilities in Istria County, specifically in the areas of Roč, Sveti Lovreč, and Kanfanar. Beyond technical assessments, the research examines the level of acceptance among diverse stakeholders in Istria County, encompassing farmers, non-governmental organizations, residents, as well as municipal and regional decision-makers. This assessment seeks to unravel the many of factors influencing public acceptance of treated wastewater, including concerns related to pathogenic microorganisms, safety perceptions, and overall satisfaction. With increasing demand for sustainable water management solutions due to water scarcity and the impacts of climate change, the reuse of treated wastewater emerges as a viable alternative. Key elements in achieving this goal include public education, access to credible information, and addressing concerns such as fears related to pathogens, perceived risks, and overall dissatisfaction. Ultimately, this study serves as an exploration of the potential of wastewater and its responsible integration into agriculture, thereby paving the way for sustainable water management practices in the future.

In conclusion, the comprehensive exploration of wastewater reuse for agricultural irrigation in Istria County reveals a multifaceted landscape shaped by the perspectives of diverse stakeholders, as shown through survey responses and water analysis. The survey, which engaged NGOs, agricultural producers, scientists, and municipal officials, provided invaluable insights into the potential and challenges of utilizing treated wastewater in agriculture. Demographically, the respondents represented a balanced distribution of genders and age groups, boasting high educational achievement. Their occupational diversity encompassed the agricultural sector and local governance, ensuring a broad spectrum of viewpoints that align with the region's intricate social fabric. The survey revealed characteristics of local businesses, with a predominant presence of family-based agricultural enterprises characterized by relatively modest land holdings. It is evident that the agricultural community is already demonstrating a predisposition towards sustainability, backed up by the prevalent use of water-efficient drip irrigation methods. These practices align with the broader objective of conserving precious freshwater resources.

Opinions on summertime water restrictions varied, underscoring the balance between water resource management and the maintenance of agricultural prosperity. While some respondents expressed concerns about potential restrictions, there was also a notable willingness to explore alternative water sources like treated wastewater for irrigation. This sentiment highlights the evolving mindset among stakeholders toward more sustainable agricultural practices. Complementing the survey, water analysis results shed light on essential water quality parameters, reinforcing the importance of stringent treatment processes to address safety concerns. This aspect is important in assuring stakeholders of the reliability and safety of treated wastewater for agricultural purposes. Controlled treatment methods, as supported by regulations and standards, are fundamental in gaining the trust of the agricultural community and broader society. Moreover, the potential benefits of using treated wastewater in agriculture are substantial. It presents an opportunity to simultaneously address water scarcity challenges, mitigate the environmental impact of wastewater discharge, and support agricultural productivity. By reusing treated wastewater, the region can increase its water resources, enhance soil fertility, and reduce the pressure on natural water bodies. This approach aligns with global sustainability goals and exemplifies Istria County's commitment to responsible resource management.

While this research aimed to comprehensively evaluate the potential of treated wastewater reuse in agriculture within Istria County, it is important to acknowledge certain limitations. The dataset used in this study, although rich in essential parameters, lacks information regarding Biochemical Oxygen Demand (BOD) values, the presence of micro-plastics, concentrations of heavy metals in the treated wastewater, and the assessment of biological activity. These omissions represent constraints in fully characterizing the treated wastewater, as they are integral to understanding its overall quality and potential environmental impacts. BOD values, for instance, are vital indicators of organic pollution and biodegradability, while the presence of micro-plastics and heavy metals can pose risks to both agricultural ecosystems and human health. Additionally, assessing biological activity in the treated wastewater could offer insights into its ecological compatibility. Future research may benefit from addressing these limitations to provide a more holistic understanding of wastewater reuse in agriculture.

In essence, Istria County stands at a key point, with a wealth of natural water resources and opportunities for irrigation. Leveraging these resources responsibly and inclusively necessitates informed decision-making, community engagement, and policy formulation. Bridging the information gap, ensuring water quality, and fostering collaboration among stakeholders will be important steps toward realizing the promise of wastewater reuse in agriculture and securing a sustainable future for this remarkable region. The potential for treated wastewater to serve as a valuable resource in bolstering agricultural production and mitigating water scarcity issues should not be underestimated.

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9. Attachment

9.1. Survey

Upotreba pročišćenih otpadnih voda u poljoprivredi za navodnjavanje, na području Istarske županije.

Poštovani kolegice i kolege,

Glavni cilj ovog anketnog ispitivanja je prikupljanje podataka, mišljenja i stavova ispitanika iz Istarske Županije, o korištenju pročišćenih otpadnih voda u poljoprivredi za navodnjavanje. Prikupljeni podaci bit će korišteni u izradi diplomskog rada: Ponovna uporaba pročišćenih otpadnih voda u poljoprivredi i društvena prihvaćenost u Istarskoj Županiji.

Prikupljeni podaci biti će korišteni u izradi diplomskog rada „Ponovna uporaba pročišćenih otpadnih voda u poljoprivredi i društvena prihvaćenost u Istarskoj Županiji“, studenta Ivana Puža, pod mentorstvom izv. prof. dr. sc. Monike Zovko, na Agronomskom fakultetu u Zagrebu.

Vaše sudjelovanje je dobrovoljno. Vaša je anonimnost u potpunosti zajamčena, a dobiveni rezultati koristit će se isključivo u znanstvene svrhe.

Sukladno odredbama Opće uredbe o zaštiti podataka (EU) 2016/679 (GDPR), svi podaci će biti registrirani u našoj bazi podataka te će se obrađivati ručno i automatizirano sukladno GDPR-u i nacionalnom zakonodavstvu, koje definira provedbu uredbe o zaštiti podataka.

Zahvaljujemo Vam na pomoći i sudjelovanju.

1. Spol *

- [ ] Ž
- [ ] M

2. Godine *

- [ ] 18 - 25
- [ ] 26 - 35
- [ ] 36 - 45
- [ ] 46 - 55
- [ ] 56 - 65
- [ ] 66+

3. Koje obrazovanje ste završili? *

- [ ] 1. Bez škole i nepotpuna osnovna škola
- [ ] 2. Osnovna škola
- [ ] 3. Srednja trogodišnja škola
- [ ] 4. Srednja četverogodišnja škola
- [ ] 5. Viša škola ili 3 godine preddiplomskog studija
- [ ] 6. Diplomski studiji i više

4. Koje je Vaše zanimanje, posao koji pretežito obavljate? *

- [ ] 1. Poljoprivrednik
- [ ] 2. Službenik
- [ ] 3. Poduzetnik
- [ ] 4. Nezaposlen
- [ ] 5. Umirovljenik
- [ ] Ostalo: ____________________

5. Oblik poslovanja Vašeg poljoprivrednog gospodarstva? *

- [ ] 1. SOPG
- [ ] 2. OPG
- [ ] 3. Obrt
- [ ] 4. d.o.o.
- [ ] 5. d.d.
- [ ] Ostalo: ____________________

6. U kojoj je općini je Vaše zemljište koje navodnjavate (ili želite početi navodnjavati)? *

- ○ 1. Roč (Općina Buzet)
- ○ 2. Sv. Lovreč (Općina Sv. Lovreč)
- ○ 3. Kanfanar (Općina Kanfanar)
- ○ Ostalo: ____________________

7. Veličina korištenog poljoprivrednog zemljišta? *

- 1. 0 – 0,9 ha
- 2. 1 – 1,9 ha
- 3. 2 - 3,9 ha
- 4. 4 – 9,9 ha
- 5. 10 – 19,9 ha
- 6. 20 – 39,9 ha
- 7. 40 – 99 ha
- 8. 100 ha +

8. Koristite li na Vašem gospodarstvu sustav za navodnjavanje poljoprivrednog zemljišta? *

- 1. Da, koristim
- 2. Ne, ne koristim

9. Voda za navodnjavanje neophodna je na mom gospodarstvu. *

- 1. Da, slažem se
- 2. Ne, ne slažem se
- 3. Nisam sigurna/an

10. Koja je veličina zemljišta koju bi željeli navodnjavati ili navodnjavate? *Upišite* *

Vaš odgovor

11. Ako koristite sustav navodnjavanja, navedite koji sustav koristite? *Moguće odabrati više odgovora:* *

- ○ 1. Kapanjem
- ○ 2. Potapanjem
- ○ 3. Kišenjem
- ○ 4. Raspršivač ili Mini-raspršivač
- ○ 5. Tifon
- ○ 6. Samohodni sustavi
- ◉ 7. Ručno
- ○ 8. Ništa od navedenog

12. Molimo Navedite iz kojih izvora koristite Vodu za navodnjavanje? *

- ○ 1. Voda iz izvora
- ○ 2. Voda iz rijeke ili potoka
- ○ 3. Voda iz jezera ili drugog prirodnog akumulacijskog oblika
- ○ 4. Voda iz umjetnog jezera ili drugog akumulacijskog oblika
- ○ 5. Vodovodna voda
- ○ 6. Pročišćena otpadna voda

13. Smatrate li da treba uvoditi restrikcije za korištenje vode u ljetnom periodu? *

- ☐ 1. Da, smatram da treba
- ☐ 2. Ne, smatram da ne treba

14. Bi li Vam uvođenje restrikcija vode otežalo poljoprivrednu proizvodnju? *

- [ ] 1. Da, uvođenje restrikcija otežalo bi mi poljoprivrednu proizvodnju.
- [ ] 2. Ne, uvođenje restrikcija ne bi mi otežalo poljoprivrednu proizvodnju.

Kada se dogodi restrikcija vode, kako ste do sada navodnjavali? *Moguće više odgovora:* *

- ◯ 1. Prilagođavanjem sustava za navodnjavanje
- ◯ 2. Korištenje akumulirane kišnice
- ◯ 3. Smanjeno korištenje sustava za navodnjavanje
- ◯ 4. Ne korištenje sustava za navodnjavanje
- ◯ Ostalo: ____________________

16. Jeste li čuli za pročišćene otpadne vode u poljoprivredi? *

- [ ] 1. Jesam
- [ ] 2. Ne, nisam
- [ ] 3. Ne znam, nisam sigurna/an

17. Jesu li Vam dostupne informacije o mogućnosti korištenja pročišćenih otpadnih voda u poljoprivredi? *

- [ ] 1. Nedostaju mi informacije o pročišćenim otpadnim vodama
- [ ] 2. Dostupne su mi informacije o pročišćenim otpadnim vodama

18. Poznajete li nekoga da koristi pročišćene otpadne vode na njihovim površinama ili plastenicima? *

- [ ] 1. Da, sigurno poznajem
- [ ] 2. Ne, ne poznajem
- [ ] 3. Ne znam, nisam sigurna/an

19. Želite li se dodatno informirati o mogućnosti korištenja pročišćenih otpadnih voda za navodnjavanje u poljoprivredi? *

- [ ] 1. Da, želim se informirati
- [ ] 2. Ne, ne želim se informirati
- [ ] 3. Ne znam, nisam sigurna/an

20. Što mislite upotrebi otpadnih voda u poljoprivredi za navodnjavanje? *

- [ ] 1. Mislim da bi to bilo prikladno rješenje
- [ ] 2. Mislim da to nije prikladno rješenje
- [ ] 3. Nisam sigurna/an

21. Koristite li u Vašem gospodarstvu tretirane otpadne vode iz pročišćivača za navodnjavanje u poljoprivredi? *

- [ ] 1. Da, koristim
- [ ] 2. Ne, ne koristim
- [ ] 3. Nisam sigurna/an

22. Biste li htjeli da Vam u periodu restrikcija, pročišćene otpadne vode budu dostupne za navodnjavanje? *

- [ ] 1. Da, htio/htjela bih
- [ ] 2. Ne, ne bih htio/htjela
- [ ] 3. Nisam sigurna/an

23. Zabrinut/a sam da kvaliteta pročišćene otpadne vode nije dobra za navodnjavanje. *

- [ ] 1. Da, zabrinut/a sam
- [ ] 2. Ne, nisam zabrinut/a
- [ ] 3. Nisam sigurna/an

24. Kada bi znanstvena analiza pročišćene otpadne vode pokazala da je potpuno sigurna za korištenje u poljoprivredi, odlučio bih: *

- [ ] 1. Da, koristio/la bih otpadne vode za navodnjavanje u poljoprivredi.
- [ ] 2. Ne, ne bih koristio/la otpadne vode za navodnjavanje u poljoprivredi.
- [ ] 3. Nisam sigurna/an

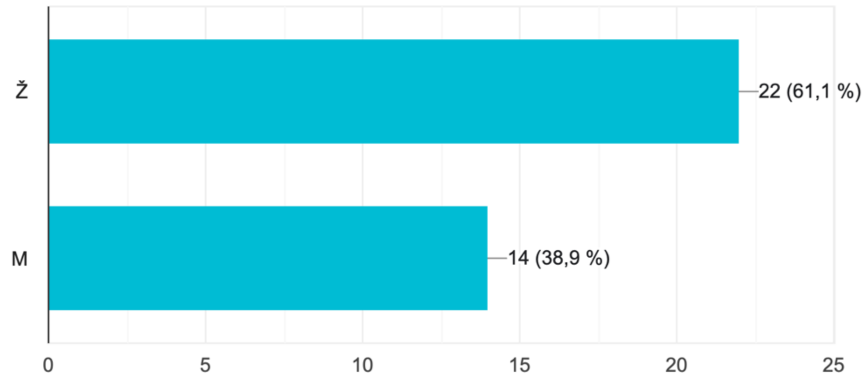
Molimo upišite Vaš komentar o mogućnosti korištenja pročišćenih otpadnih voda u poljoprivredi. (Što Vas zanima u vezi pročišćenih otpadnih voda, znate li tuđa iskustva s korištenjem pročišćenih otpadnih voda, imate li dileme oko korištenje otpadnih voda i slično). *

Vaš odgovor

9.2. Survey results

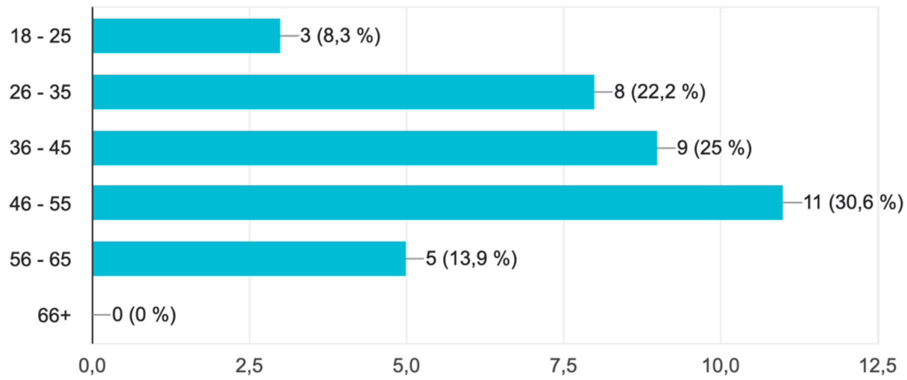
1. Spol

36 odgovora



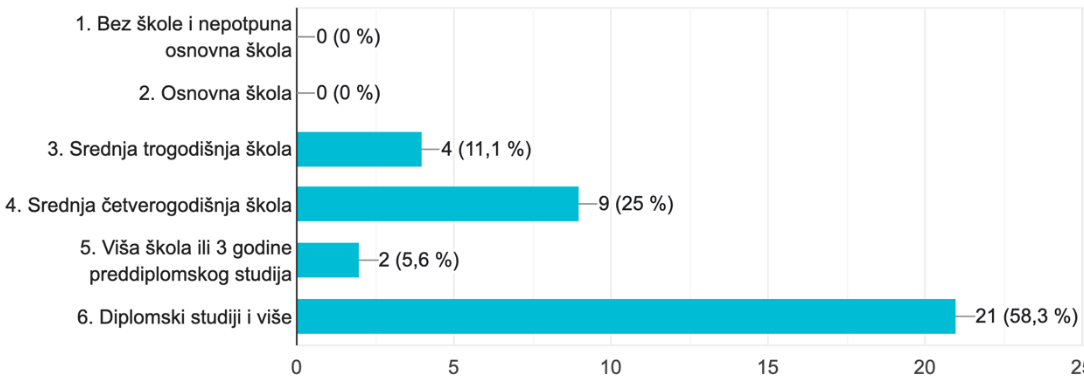
2. Godine

36 odgovora



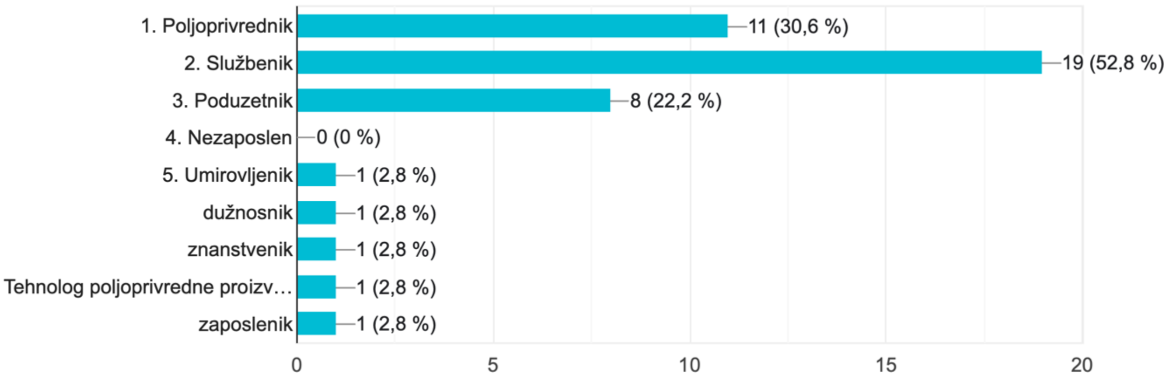
3. Koje obrazovanje ste završili?

36 odgovora



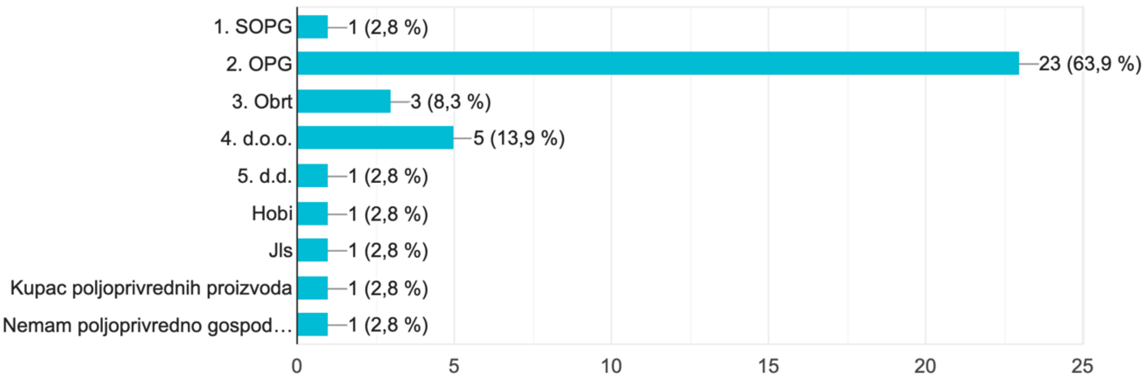
4. Koje je Vaše zanimanje, posao koji pretežito obavljate?

36 odgovora



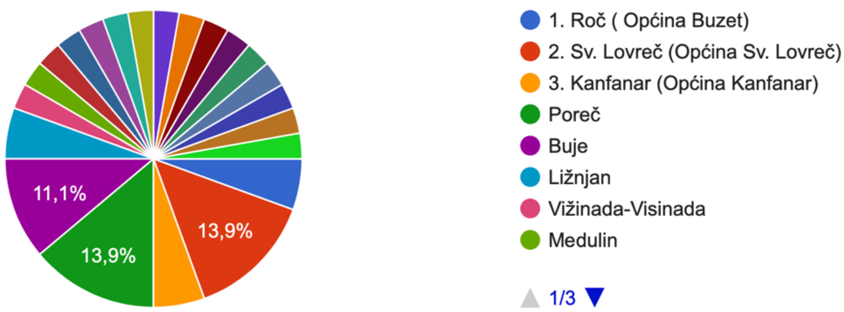
5. Oblik poslovanja Vašeg poljoprivrednog gospodarstva?

36 odgovora

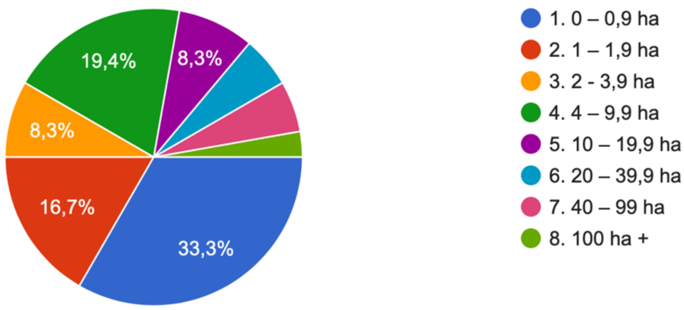


6. U kojoj je općini je Vaše zemljište koje navodnjavate (ili želite početi navodnjavati)?

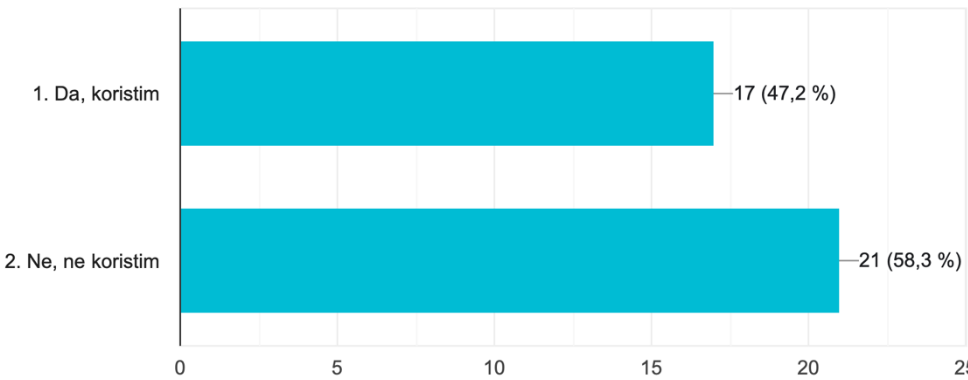
36 odgovora



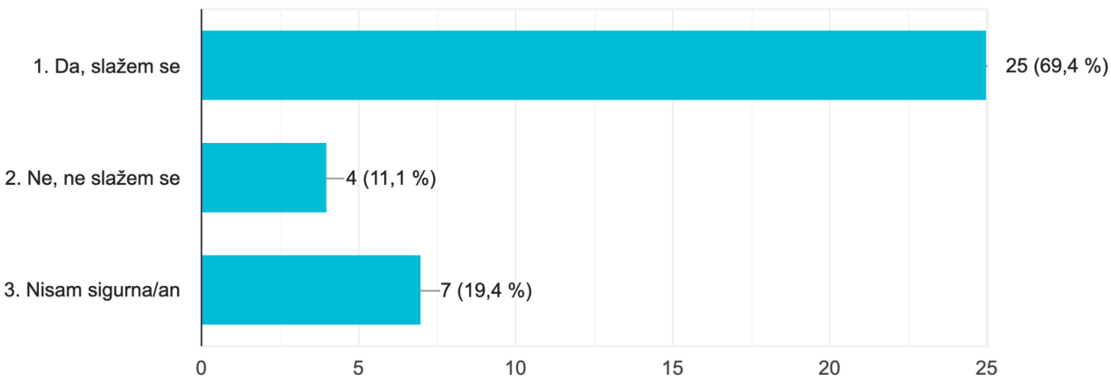
7. Veličina korištenog poljoprivrednog zemljišta?
36 odgovora



8. Koristite li na Vašem gospodarstvu sustav za navodnjavanje poljoprivrednog zemljišta?
36 odgovora

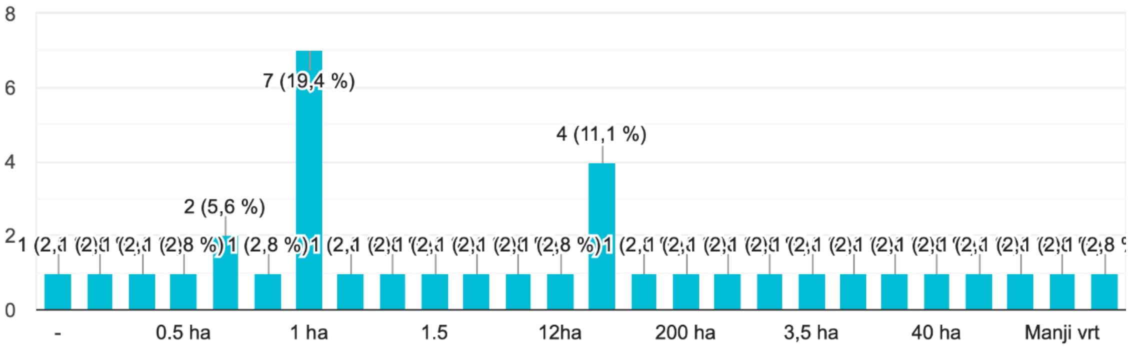


9. Voda za navodnjavanje neophodna je na mom gospodarstvu.
36 odgovora



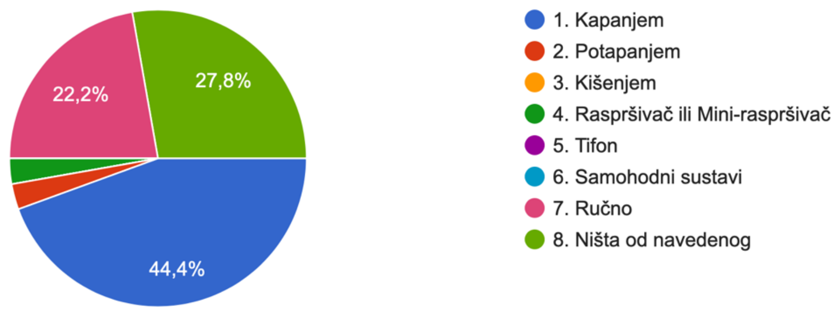
10. Koja je veličina zemljišta koju bi željeli navodnjavati ili navodnjavate? Upišite

36 odgovora



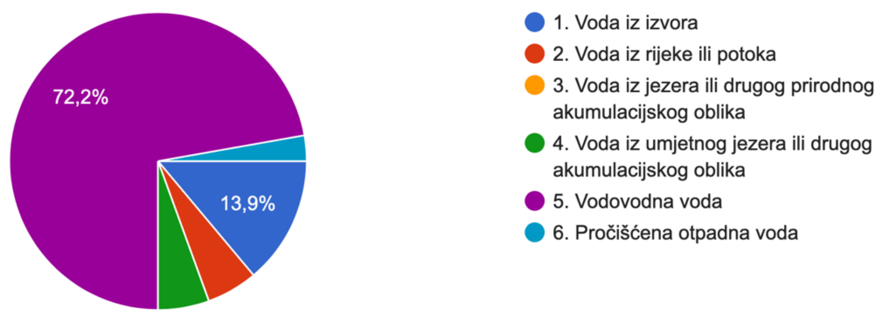
11. Ako koristite sustav navodnjavanja, navedite koji sustav koristite? Moguće odabrati više odgovora:

36 odgovora

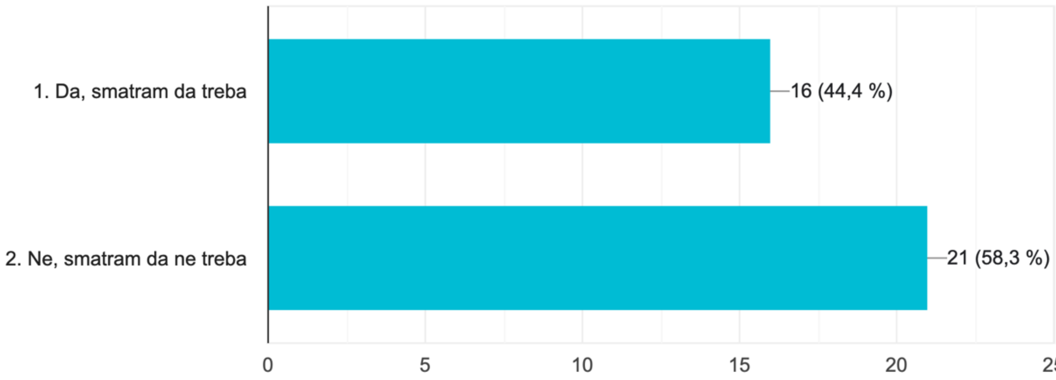


12. Molimo Navedite iz kojih izvora koristite Vodu za navodnjavanje?

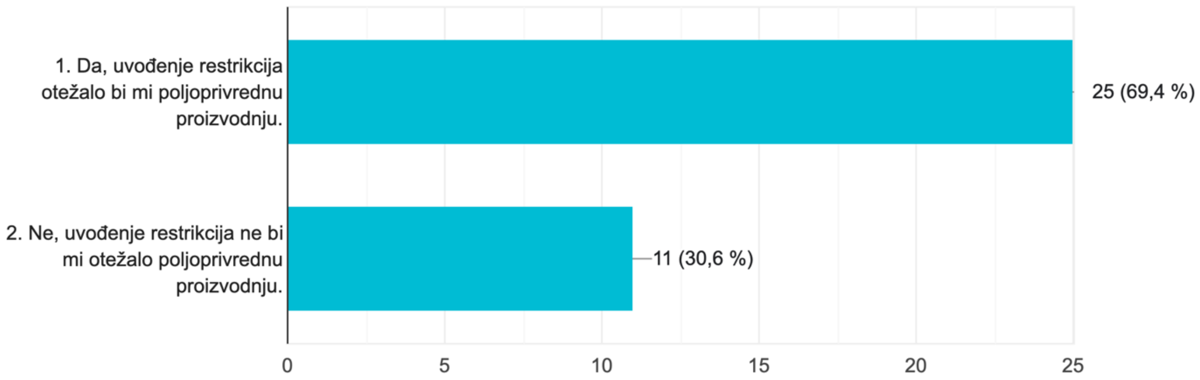
36 odgovora



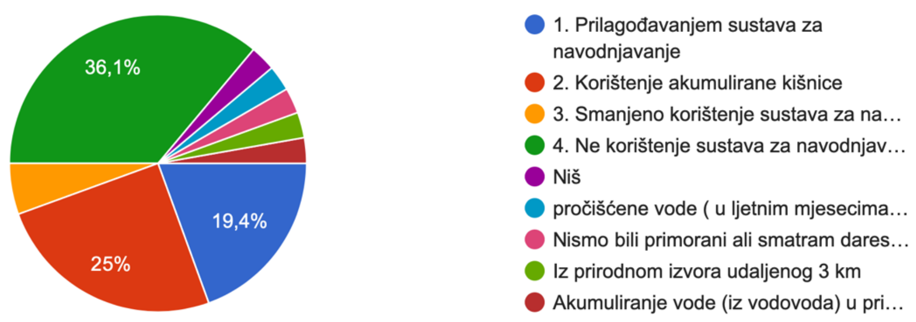
13. Smatrate li da treba uvoditi restrikcije za korištenje vode u ljetnom periodu?
36 odgovora



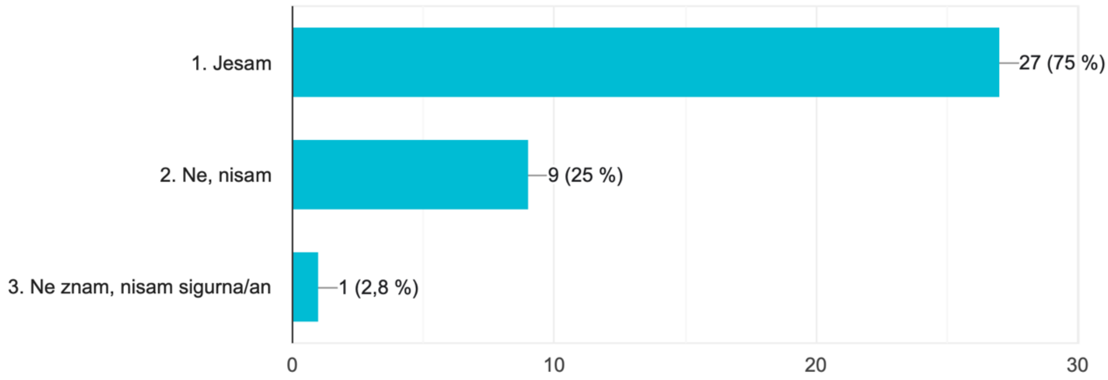
14. Bi li Vam uvođenje restrikcija vode otežalo poljoprivrednu proizvodnju?
36 odgovora



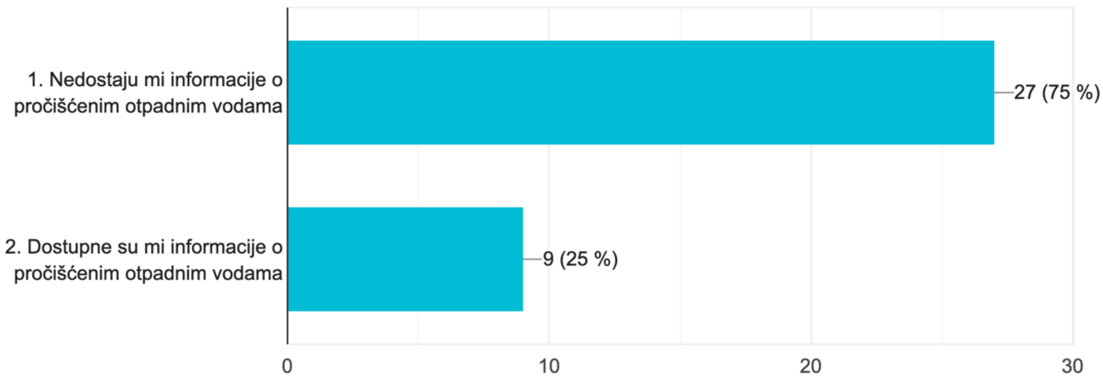
Kada se dogodi restrikcija vode, kako ste do sada navodnjavali? Moguće više odgovora:
36 odgovora



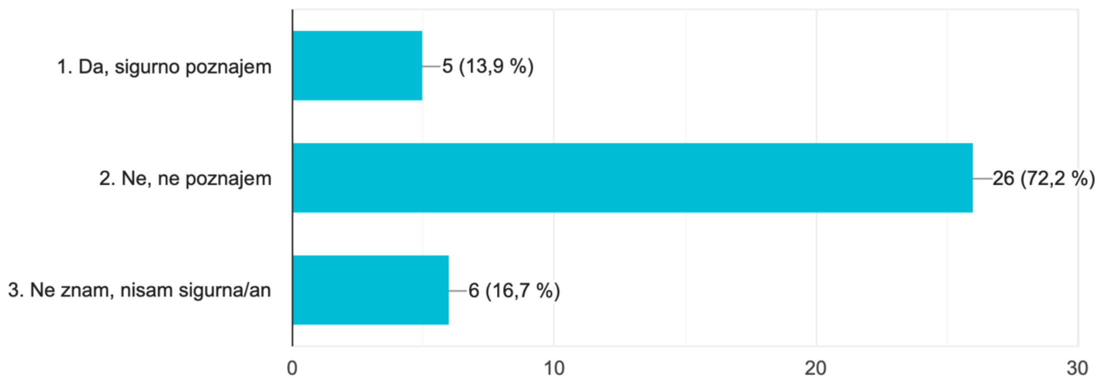
16. Jeste li čuli za pročišćene otpadne vode u poljoprivredi?
36 odgovora



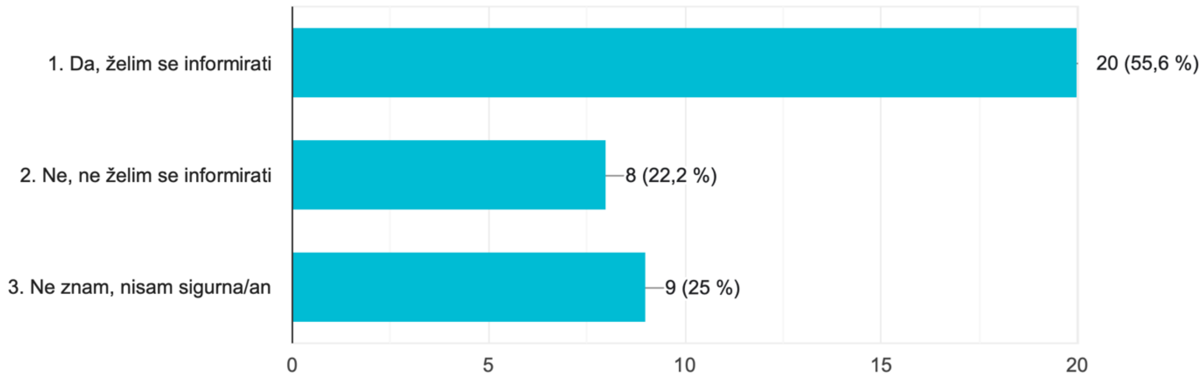
17. Jesu li Vam dostupne informacije o mogućnosti korištenja pročišćenih otpadnih voda u poljoprivredi?
36 odgovora



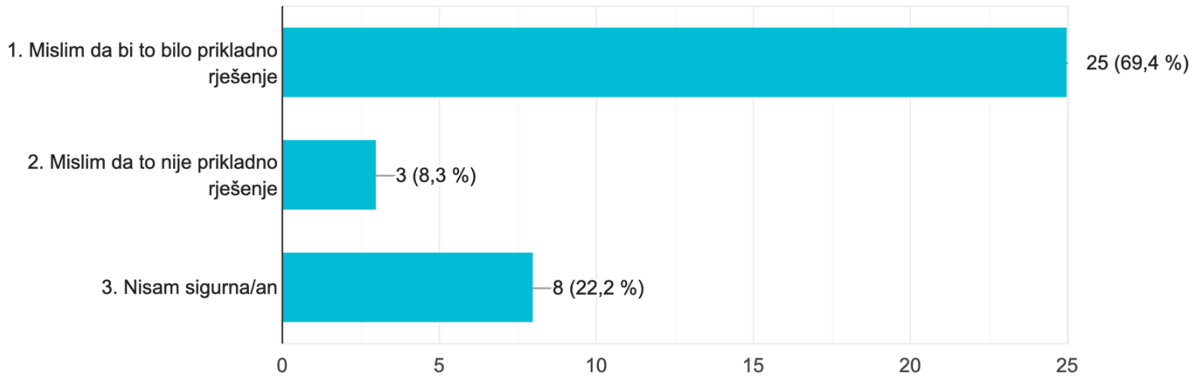
18. Poznajete li nekoga da koristi pročišćene otpadne vode na njihovim površinama ili plastenicima?
36 odgovora



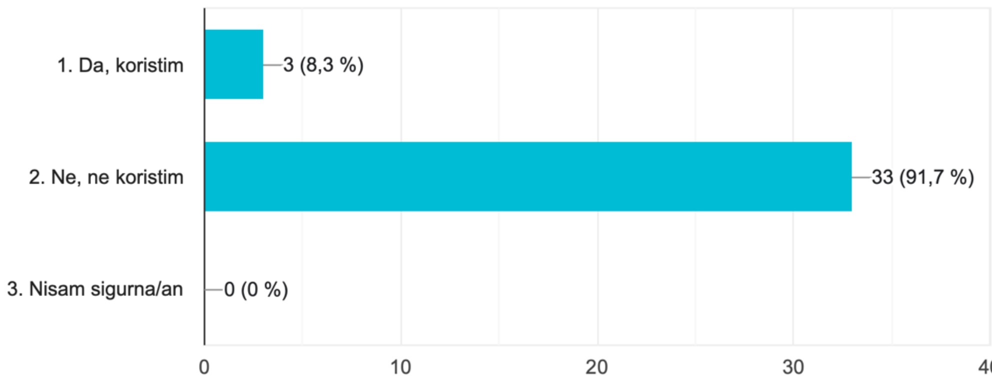
19. Želite li se dodatno informirati o mogućnosti korištenja pročišćenih otpadnih voda za navodnjavanje u poljoprivredi?
36 odgovora



20. Što mislite upotrebi otpadnih voda u poljoprivredi za navodnjavanje?
36 odgovora

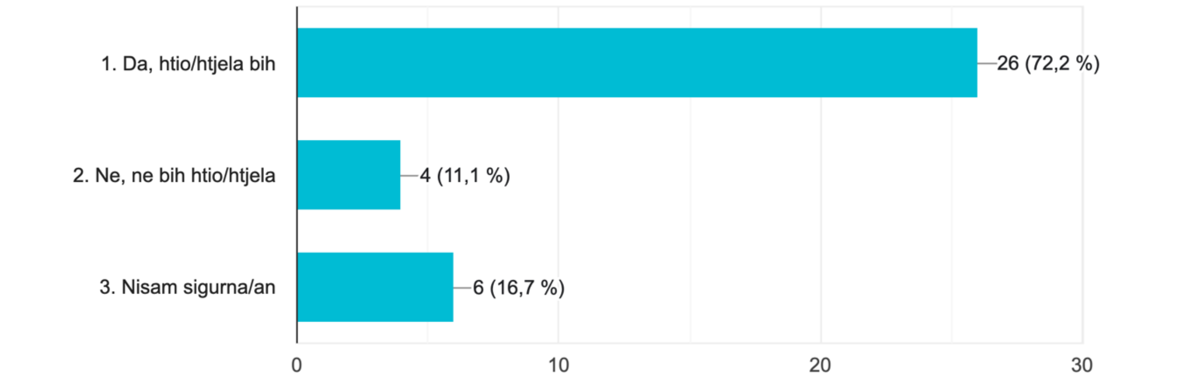


21. Koristite li u Vašem gospodarstvu tretirane otpadne vode iz pročišćivača za navodnjavanje u poljoprivredi?
36 odgovora



22. Biste li htjeli da Vam u periodu restrikcija, pročišćene otpadne vode budu dostupne za navodnjavanje?

36 odgovora

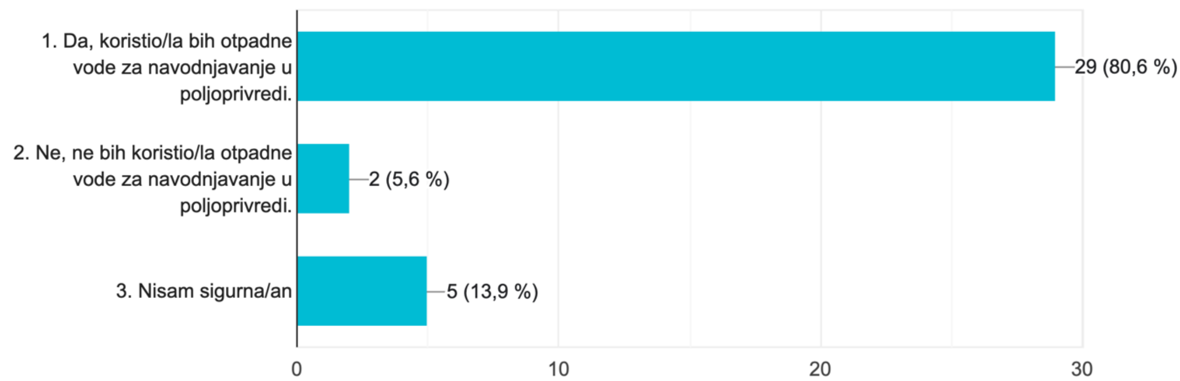


23. Zabrinut/a sam da kvaliteta pročišćene otpadne vode nije dobra za navodnjavanje.

36 odgovora

24. Kada bi znanstvena analiza pročišćene otpadne vode pokazala da je potpuno sigurna za korištenje u poljoprivredi, odlučio bih:

36 odgovora



9.3. List of figures

9.4. List of tables

Životopis

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Gredice 143, 10000 Zagreb
ivan.puz@gmail.com
+385981720174

Ivan Puž, rođen u Kopru 22. siječnja 1988. godine, visoko je motivirana i prilagodljiva osoba s visokim obrazovnim u polju poljoprivrede, ekoloških znanosti i upravljanja resursima. Posjeduje diplomu magistra inženjera poljoprivrede s Agronomskog fakulteta Sveučilišta u Zagrebu. Ivan je također prvostupnik mediteranske poljoprivrede s Veleučilišta u Rijeci, te srednjoškolska sprema u elektrotehnici iz Srednje škole Buje.

S obzirom na svoju C2 stručnost u engleskom i talijanskom jeziku, koristan za međunarodni i interdisciplinarni rad. Njegove tehničke vještine uključuju poznavanje Microsoft Office-a i upotrebu interneta. Osim svojih akademskih i tehničkih vještina, Ivan posjeduje važeću vozačku dozvolu, što ga čini svestranim resursom za poslove koji zahtijevaju mobilnost i putovanja.

Ivan Puž odlično surađuje u timskom radu i može se prilagoditi različitim radnim okolinama. Njegov duh suradnje i prilagodljivost čine ga idealnim kandidatom za poslove koji zahtijevaju učinkovitu suradnju i fleksibilnost.

Osim svojih profesionalnih kvalifikacija, Ivan je strastveni glazbenik koji je vješt u sviranju perkusija, bubnjeva i pjevanju. Uživa u različitim aktivnostima na otvorenom, uključujući planinarenje, vožnja brdskim biciklom, skijanje, plivanje i ronjenje.

Ivan Puž posvećen je doprinosu održivom upravljanju resursima i unaprjeđenju poljoprivrednih praksi kako bi se stvorila okolišno prihvatljivija i učinkovitija budućnost.

Englesi jezik : C2
Talijanski jezik: C2

MREŽE I ČLANSTVA
Membership Former Member of Foto klub Mrak , Buje
Membership Former longtime member of the Red Cross in Buje
VOZAČKA DOZVOLA
Vozačka dozvola: B
ORGANIZACIJSKE VJEŠTINE
Organisation, Sound and Light, Stage Involved in organising several events and festivals in Buje area, Istria. Familiar with the process of organising and layout. Sound and light skills, as well as stage manager skills.
KOMUNIKACIJSKE I MEĐULJUDSKE VJEŠTINE
Personal skills Teamwork, Dedication, Punctuality, Hard work, Personal Development, Humble and thankful