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Reuse of Treated Municipal Wastewater for the Production of Water for Agriculture

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Abstract: Treated municipal wastewater may be a source of water that can be used for a wide range of industrial applications, municipal services, agriculture, and environmental protection. It must meet the criteria for environmental protection and human and animal health. Directive 2007/2/EC of the European Parliament and the Council covers the shared use of spatial information, including data sets on various issues in the field of environmental protection. The provisions of the above regulation on access to information and agreements mustn't constitute a separate legal system. Data provided by the Member States are necessary for the Commission to conduct monitoring. At present, it can be stated that the reuse of treated municipal wastewater reflects the state of scientific knowledge and international standards and practices of using treated wastewater for agricultural irrigation. Such policy promotes a circular economy, supports adaptation to climate change, and contributes to achieving the assumed objectives. Published Regulation (EU) 2020/741 of the European Parliament and of the Council of 25 May 2020 on minimum requirements for water reuse does not exclude food business operators from obtaining water quality parameters required to ensure compliance with the provisions of this regulation. New solutions for eliminating micropollutants from treated municipal wastewater will support these assumptions.

Keywords: municipal wastewater, wastewater treatment, treated wastewater quality classes, filtration, water recovery, EU legislation

1. Introduction

Climate change and deteriorating water resources in most EU countries, including Poland, force actions to recover more water from various sources. An increasing shortage of water and deterioration of its quality are observed. The development of urban agglomerations, agriculture, unpredictable weather phenomena, and droughts explain it. Countermeasures have already been taken in the European Union countries, including Poland. A significant administrative action is the act of the European Parliament of 12 February 2019. Regulation (EU) 2020/741 of the European Parliament and the Council of 25 May 2020 on minimum requirements for water reuse was published. In some European countries (Germany, Denmark, France, Italy), this type of "recycled" water from municipal wastewater treatment is increasingly used. The first installations to recover water from municipal wastewater are already being implemented in Poland. This process is supported by the "Treaty on the Functioning of the European Union", particularly its Article 192 section 1 and also:

- opinion of the European Economic and Social Committee (Journal of Laws C 110, 22.3.2019, p. 94),
- opinion of the Committee of the Regions (Journal of Laws C 86, 7.3.2019, p. 353),
- position of the European Parliament of 12 February 2019 (not yet published in the Official Journal) and position of the Council at first reading of 7 April 2020 (Journal of Laws C 147, 4.5.2020, p. 1).

The use of water resources accumulated in treated wastewater through its further purification (3rd stage of treatment) can minimize the shortage of water used for irrigation of agricultural land. It also leads to a reduced exploitation of surface and groundwater bodies. In Directive 2000/60/EC of the European Parliament and the Council of 23 October 2000 establishing a framework for EU action in the field of water policy (Journal of Laws L 327, 22.12.2000, p. 1), the reuse of water, in combination with the promotion of the use of water-efficient technologies and water-saving irrigation techniques in industry. It is stated that Member States may implement the objectives of this Directive in terms of the excellent status of surface and groundwater bodies in quantitative and qualitative terms. Council Directive 91/271/EEC of 21 May 1991 concerns the treatment of municipal wastewater so that treated wastewater is reused whenever appropriate.

The Commission Communication of 14 November 2012, "*A Blueprint to Safeguard Europe's Water Resources*", refers to this issue by pointing out the need to create an instrument that would regulate water reuse standards at the EU level to remove obstacles to the widespread use of alternative water supply methods that can help reduce water scarcity and mitigate the vulnerability of water supply systems. It is believed that the reuse of treated wastewater, including municipal, has a more minor impact on the environment than other

alternative water supply sources, such as water transfers or desalination. Nevertheless, the recycling of reused treated wastewater is partly due to the high operational costs of wastewater treatment systems and the lack of EU environmental and health standards for water reuse, in particular concerning agricultural products and the risk of its negative impact on the environment and potentially on the health of residents using treated sewage, for example for irrigation of agricultural land. In this case, the standards for requirements related to agricultural products should correspond to the requirements applicable to water quality and its monitoring, based on the technical reports of the Joint Research Centre of the Commission, and reflect international standards for water reuse. If necessary, more stringent or additional requirements for reclaimed water quality may be processed by the appropriate regional or national environmental control authorities. It should also be remembered that reclaimed water contains several fertilizing components, which can supplement a whole range of mineral fertilizers. The state's role is to promote the initiative of using these components in treated wastewater as fertilizers in agriculture or forestry. Thus, there is a possibility of including fertilizing components (nitrogen, phosphorus, potassium) in natural biochemical cycles.

Also, municipal sewage treatment plants should be modernized. Innovative programs, economic incentives, and noticeable socio-economic and environmental benefits can support this process. Conducting the above activities should be consistent with the EU water policy and, at the same time, contribute to achieving the sustainable development goals, as published in the "*2030 Agenda for Sustainable Development*" of the United Nations, particularly in the implementation of goal 6. That goal consists of ensuring access to water and sanitation for all people through sustainable management of water resources and increasing water recycling and safe reuse of water worldwide significantly (Article 37 of the Charter of Fundamental Rights of the European Union) regarding environmental protection.

Member States should adopt requirements for the quality of water intended for human consumption, per Council Directive 98/83/EC of 3 November 1998. To protect the environment and human and animal health, operators of water reclamation plants should monitor the quality of reclaimed water. Several provisions supplement the requirements of other Union legislation, considering these recommendations, particularly those concerning potential risks to health and the environment. Regulation (EC) No 852/2004 on general rules for food business operators covering the production, processing, distribution, and introduction of food for human consumption was issued.

Treated municipal wastewater is a source of water that can be used widely in industry, municipal services, agriculture, and environmental protection. The apparent condition is that they must meet the criteria for environmental protection and human and animal health. Undoubtedly, using water obtained from treated municipal wastewater may encounter resistance not only from local communities. In this case, on the side of the relevant environmental protection authorities and producers of water obtained from treated municipal wastewater, conscious information about the financial and environmental benefits is needed.

Directive 2007/2/EC of the European Parliament and the Council covers sharing spatial information, including data sets on various environmental issues. The provisions of the above Regulation on access to information and arrangements mustn't constitute a separate legal regime. Data provided by Member States are necessary for the Commission to monitor and evaluate this Regulation about achieving the objectives it intends to serve.

At present, it can be stated that the reuse of treated municipal wastewater reflects the state of scientific knowledge and international standards and practices for the use of treated water for agricultural irrigation, thus ensuring a high level of protection of the environment and human and animal health. Promoting the circular economy, supporting adaptation to climate change, and contributing to the achievement of the objectives of Directive 2000/60/EC will make it possible to address in a coordinated way across the whole EU the problem of water scarcity and the resulting pressure on water resources, thus contributing to the smooth functioning of the internal market. Council Directive 91/271/EEC of 21 May 1991 applies to all cases where treated municipal wastewater is reused for agricultural irrigation.

The Regulation (EU) 2020/741 of the European Parliament and of the Council of 25 May 2020 on minimum requirements for water reuse does not exclude food business operators from obtaining the water quality parameters required to ensure compliance with the provisions of this Regulation by using, at a subsequent stage, several water treatment options, independently or in combination with non-treatment options, or using alternative water resources for agricultural irrigation. The Regulation contains obligations for water reclamation plant operators and obligations regarding reclaimed water quality. This Regulation also indicates:

- the forms of cooperation between Member States,
- information and dissemination of knowledge,
- informing the public about the possibility of using water for irrigation in agriculture,
- the risk management plan for water reuse,

- obligations regarding permits for the supply of water intended for irrigation in agriculture in the manner specified in the cited regulation,
- control of compliance with the conditions specified in the permit using:
    - on-site inspections,
    - monitoring data, in particular, compliance with this regulation,
    - and any other appropriate measures.

The regulation contains information on monitoring the implementation of reclaimed water for irrigation in agriculture and the assessment carried out by the Commission – the European Environment Agency and the European Centre for Disease Prevention and Control. The selected essential elements of the regulation shall apply from 26 June 2023.

2. Reuse of Municipal Wastewater – Quality Parameters

One of the forms of treated municipal wastewater reuse for water production has been approved in the EU Member States. Treated municipal wastewater is discharged into surface waters without causing an increase in the concentration of pollutants. In addition to water being used for agricultural purposes, other applications are increasingly common, including in England, France, and Germany. We also have the first Polish experience in this area, with examples of new technologies implemented into municipal wastewater treatment (Szymański et al. 2016, 2018). In this area, new innovative technologies for wastewater treatment are presented as the third stage of treatment. The research results using the latest technologies in municipal sewage treatment are presented in this study.

Examples of water applications from municipal wastewater treatment (stage III) are illustrated in Table 1.

Table 1. Classes of reclaimed water allowed for usage in agriculture and irrigation methods

Minimum quality class of reclaimed water	Crop category (*)	Irrigation method
A	All plants intended for consumption in a raw state, the edible part of which is in direct contact with reclaimed water and root crops intended for consumption in a raw state	All irrigation methods
B	Crops for raw consumption, the edible part of which is produced above ground level and does not come into direct contact with reclaimed water, crops for food after processing, and non-food crops, including crops used as feed for animals used for milk or meat production	All irrigation methods
C	Crops intended for raw consumption, the edible part of which is produced above ground level and does not come into direct contact with reclaimed water, crops intended for consumption after processing, and non-food crops, including crops intended for feeding animals used for milk or meat production	Drip irrigation or other irrigation method that avoids direct contact with the edible part of the crop
D	Industrial crops, energy crops, and crops that are planted	All irrigation methods

(*) If the same type of irrigated crop falls into several categories, the most stringent requirements apply

According to EU recommendations, these waters are divided into 4 classes (A, B, C, D), considering that the minimum quality class of reclaimed water may apply to several categories of irrigated crops. These requirements are the strictest. Drip irrigation at a small water flow or rain imitating is also included here. Drip irrigation is a micro-irrigation system that allows plants to be watered with drops or small streams of water. It involves sprinkling water on the soil surface or introducing water directly under it at a prolonged rate (2-20 l/h) using a system of small-diameter plastic pipes equipped with holes called emitters or drippers. Group A consists of waters that can irrigate all plants consumed raw; thus, the edible parts have direct contact with water. Irrigation with water from group B limits the contact of this water with the part of the plants above ground level, as well as plants intended for processing and plants used as feed for milk or meat producers.

Waters classified in group C are subject to even more rigorous assessments due to the irrigation method. In such cases, the drip irrigation method or other method limiting direct contact with the edible part of the plant is used. In the classification of purified water obtained as a result of the third degree of municipal sewage treatment, it is permissible to use it for industrial and energy crops and crops in which the planting method is used and, therefore, for the use of all irrigation methods.

Table 2 presents the requirements for the quality of reclaimed water used for agricultural irrigation. Again, reference is made to the four quality classes of reclaimed water (A, B, C, D). The following parameters were considered in these studies: *E. coli*, BOD_5, total suspended solids, turbidity (NTU), and additional parameters (*Legionella spp*, intestinal nematodes as helminth eggs) (Ferrando-Climent et al. 2012, Liu & Wong 2013). In this case, reference was made to the EEC directive (91/271/EEC).

Table 2. Requirements for the quality of reclaimed water for agricultural irrigation

Class of reclaimed water	Indicative purpose of technology application	Quality requirements				
		E. coli (cfu/100 cm^3)	BOD_5 (mg/dm^3)	TSS (mg/dm^3)	Turbidity (NTU)	Other
A	Secondary treatment, filtration and disinfection	≤ 10	≤ 10	≤ 10	≤ 5	*Legionella spp.*: < 1 000 cfu/dm^3, if there is a risk of aerosol formation (or generation) Intestinal nematodes (helminth eggs): ≤ 1 egg/dm^3 for irrigation of pastures or forage crops
B	Secondary treatment and disinfection	≤ 100	According to EEC directive (91/271/EEC) (Annex I, Table 1)	According to EEC directive (91/271/EEC) (Annex I, Table 1)	–	
C	Secondary treatment and disinfection	≤ 1 000			–	
D	Secondary treatment and disinfection	≤ 10 000			–	

As can be seen, the most stringent restriction concerns class A quality of reclaimed water for agricultural irrigation, where secondary treatment, filtration, and disinfection are required. The following classes of recycled water are increasingly tolerant, for example, for *E. coli* class B ≤ 10, D ≤ 10,000. Other indicators such as BOD_5 and total suspended solids are allowed at levels ≤ 10 mg/dm^3 and turbidity at ≤ 5. For classes B, C, and D, the BOD_5 and total suspended solids are referred to in the provisions in the EEC directive (91/271/EEC) (Rosińska 2022). The frequency of these tests is listed in Table 3.

Table 3. Minimum routine monitoring frequencies for reclaimed water used for agricultural irrigation

Class of reclaimed water	Minimum monitoring frequency					
	E. coli	BOD_5	TSS	Turbidity	*Legionella spp.* (where applicable)	Intestinal nematodes (where applicable)
A	Once a week	Once a week	Once a week	Continuously	Twice a month	Twice a month or as determined by the operator of the water reclamation plant, depending on the number of eggs in the wastewater delivered to the plant
B	Once a week	According to EEC directive (91/271/EEC) (Annex I, Section D)	According to EEC directive (91/271/EEC) (Annex I, Section D)	–		
C	Twice a month			–		
D	Twice a month			–		

As can be seen, tests are most frequent for class A used in agriculture for agricultural irrigation (once a week). For the remaining groups, frequencies follow the EEC directive (91/271/EEC). In the case of turbidity, it should be tested continuously. *Legionella spp* should be tested twice a month, and intestinal nematodes should be tested twice a month, depending on the number of eggs in the sewage. The plant operator provides information on the quality of wastewater.

3. Examples of Application of Municipal Wastewater Treatment Methods in Terms of Their Reclamation

In many European Union countries, municipal wastewater after WWTP is subjected to secondary treatment, as the following third stage, to use in agriculture, forestry, and park areas (Ebele et al. 2017, Gilliom 2007). The available results of Swiss studies show that they are consistent with the results presented in Table 2. Removing pollutants from treated wastewater (stage III) is conducted by filtration using microfiber technology (Culligan method) and UV disinfection. That allows recovering water used to maintain urban greenery and other economic purposes. The municipal wastewater treatment system, based on the so-called fabric filter, was used for the first time in the Oldenburg (Germany) WWTP. Mineral and organic micropollutants and plastic microfibers were removed from the wastewater. It achieved a removal efficiency of about 97 percent. Practice shows that all technological assumptions are met after a year of operation. Similar installations have been launched in many European countries, including Vertolaye (France), for the pharmaceutical industry. Positive results in removing micropollutants, such as hormones and steroids, were achieved. Recycled water from the plant in Vertolaye is used to clean streets in Cannes. In Great Britain, 8 WWTPs operate in this system, including London (354,580 m^3/day of capacity, corresponding to 14,774 m^3/hour). The concentration of total phosphorus is under 0.5 mg/dm^3. In the largest WWTP in Europe (Deephams (UK)) with a daily capacity of 354,580 m^3/d, under 5 mg/dm^3 of total suspended solids was obtained (31.4 mg/dm^3 at the inlet and 3.8 mg/dm^3 at the outlet on average). Another example of the reuse of reclaimed water from WWTP is Ficarolo (Italy), which is used for tree watering and vineyards. The results of tests on wastewater treated using the Culligan method, as the third stage of treatment, are presented in Table 4. As can be seen, the composition of the treated sewage meets the criteria proposed by EU legislation (Hu et al. 2011, Yu et al. 2016).

In Poland, the WWTP in Międzyzdroje, with a technological system efficiency of Q = 576 m^3/h, was modernized in 2020 as part of the Project "Organization of sewage management of the WWTP in Międzyzdroje and modernization of the WWTP", implemented by KREVOX European Ecological Centre Warsaw. It included the start-up of the fourth stage of wastewater treatment (filtration) and UV disinfection with the possibility of using recovered water to maintain urban greenery and other economic purposes. Extended wastewater tests are underway regarding physical, chemical, and biological parameters.

4. Conclusions

1. World water shortages, including on the European continent, force the search for new technological solutions for treating municipal wastewater and restoring its status as water used in crops and, with certain restrictions, in vegetable production.
2. Without any special restrictions, wastewater obtained from municipal wastewater recycling can be used to irrigate urban parks and road installations of urban transport.
3. The results of the municipal wastewater tests after the third stage of treatment indicate the possibility of using it in various water management areas.

Table 4. Results of tests on wastewater treated in the microfibre technology process – Culligan

Quality class of reclaimed water	Crop category	Irrigation method	Indicative purpose of technology application	Quality requirements (monitoring frequency)				
				E. coli (cfu/100 cm^3)	BOD_5 (mg/dm^3)	TSS (mg/dm^3)	Turbidity (NTU)	Other
A	All plants intended for consumption in a raw state, the edible part of which is in direct contact with reclaimed water and root crops intended for consumption in a raw state	All irrigation methods	Secondary treatment, filtration and disinfection	≤ 10 (Once a week)	≤ 10 (Once a week)	≤ 10 (Once a week)	≤ 5 (Continuously)	*Legionella spp.*: < 1 000 cfu/dm^3, if there is a risk of aerosol formation (Twice a month) Intestinal nematodes (helminth eggs): ≤ 1 egg/dm^3 for irrigation of pastures or forage crops (Twice a month)
B	Crops for raw consumption, the edible part of which is produced above ground level and does not come into direct contact with reclaimed water, crops for food after processing, and non-food crops, including crops used as feed for animals used for milk or meat production	All irrigation methods	Secondary treatment and disinfection	≤ 100 (Once a week)	According to EEC directive (91/271/EEC) (Annex I, Table 1)	According to EEC directive (91/271/EEC) (Annex I, Table 1)	–	
C	Crops intended for raw consumption, the edible part of which is produced above ground level and does not come into direct contact with reclaimed water, crops intended for consumption after processing, and non-food crops, including crops intended for feeding animals used for milk or meat production	Drip irrigation or other irrigation method that avoids direct contact with the edible part of the crop	Secondary treatment and disinfection	≤ 1000 (Twice a month)			–	
D	Industrial crops, energy crops, and crops that are planted	All irrigation methods	Secondary treatment and disinfection	≤ 10 000 (Twice a month)			–	

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Krevox Company Information Materials

Culligan Company Information Materials