CURRENT STATE OF WASTEWATER USE IN IRRIGATED AGRICULTURE

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ABSTRACT

Due to climate change, the areas affected by drought and water scarcity are increasing rapidly. Thus, wastewater has become a valuable resource to the farmers because it is a consistently available source of irrigation water. At least 10% of global population consumes food from wastewater irrigation and over 20 million hectares (10% of irrigated land) are irrigated with untreated, partially treated / diluted or treated wastewater. More than 200 million farmers in 44 countries recover 15 million m^3 of treated wastewater / day for irrigation. Although in many countries there are no regulations on the quality for irrigated wastewater, there has been growing interest in the long-term effects of wastewater irrigation on human health and the environment.

INTRODUCTION

As a result of population growth, urbanization, improvement of sanitation service coverage and industrialization, large amounts of wastewater are generated worldwide.

Wastewater and agriculture are two sectors where the economic and environmental benefits of joint water management have been demonstrated through case studies around the world.

Agriculture is the most water demanding sector, accounting for about 70% of global freshwater withdrawn worldwide. Moreover, 28% of global agricultural land and 56% of the total area of irrigated land are located in areas with high (40-80%) or extremely high (> 80%) water scarcity, based on the ratio of withdrawn water to available water [5].

In arid and semi-arid regions, irrigation is essential for economically viable agriculture, while in semi-wet and wet areas, irrigation is often required as an additional measure.

On September 8, 2000, the United Nations General Assembly adopted the Millennium Development Goals. Directly related to the use of wastewater in agriculture are "Objective 1: Eradicate extreme poverty and hunger" and "Objective 7: Ensure environmental sustainability". Using wastewater in agriculture can help communities to grow more food and make better use of water resources and nutritional resources.

It is estimated that 60% more food will be needed worldwide in 2050 to feed 9 billion people, so the sustainable management and judicious use of water resources is extremely vital. This is particularly important in arid and semi-arid regions where freshwater shortages force farmers to consider all water sources that can be used economically and efficiently to irrigate their crops, to ensure their financial stability and to promote the sustainable development [2].

The reuse of treated wastewater (reclaimed water) for irrigation is not a new concept, as this practice was encountered centuries ago. It is also a valuable strategy to maximize available water resources, but the often marginal quality of the water can present some agricultural challenges. Aside from unplanned reuse in regions where farmers irrigate with waste-contaminated sources, planned reuse in agriculture is limited in comparison to its potential. Farmers have the capacity to accept reclaimed water, visible through their decision to irrigate with the resource or reject reclaimed water, perhaps demonstrated through relocation or agricultural abandonment, or investment in the development of freshwater resources such as groundwater. Wastewater irrigation is regarded both as an effective disposal form and as a form of recovery of these waters. Irrigation with wastewater can significantly mitigate the pressure on fresh water sources as well as the discharge of effluents into the environment, avoiding damage to freshwater ecosystems associated with eutrophication and algal blooms. Wastewater has a high nutritional value that can reduce fertilizer application rates and increase productivity on poor soil fertility [2].


Fig. 1. Field in arid city Dăbuleni (Dolj County, Romania – photo taken in May 2018) vs. irrigated field

It has been shown that the nutrients embodied in wastewater can increase yields as much or more than a combination of tap water and chemical fertilizer. It is also known that the use of wastewater in irrigation has additional agronomic benefits associated with soil structure and fertility, increasing both agricultural productivity and living standards in poor rural areas.

Untreated wastewater is currently used to irrigate food crops in many parts of the world, and this practice does not seem to produce significant socio-cultural repulsion, being driven solely by economic necessity. It seems that treated wastewater is much less unacceptable than untreated wastewater and, from a socio-aesthetic point of view, it is more suitable for agricultural use.

Wastewater reuse in agricultural irrigation faces a roadblock: the public concern over the potential accumulation of contaminants of emerging concern (CECs) into human diet. Nevertheless, any public concerns about wastewater reuse can be mitigated by appropriate information programs [15].

However, the reuse of treated wastewater especially for agricultural crop irrigation is a practice encouraged by governments and official entities around the world. To manage health and environmental hazards, the World Health Organization (WHO) provides guidelines for the safe reuse of wastewater in agriculture, including treatment and non-treatment options, which take into account the entire chain - from cultivation on consumption [16].

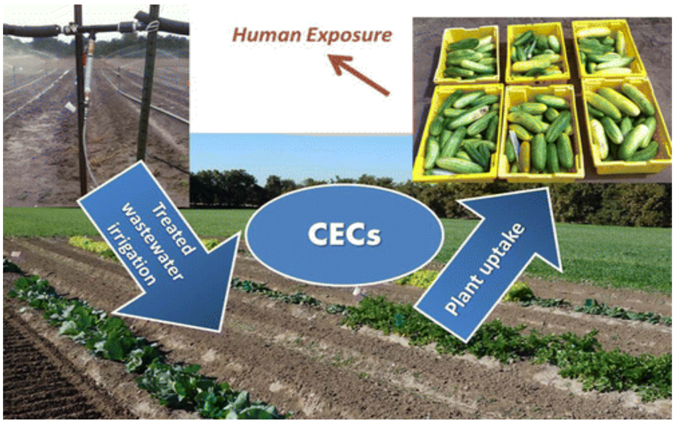

Fig. 2. Wastewater reuse – plant uptake of contaminants – human exposure [11]

MATERIAL AND METHOD

The most suitable treatment method that can be applied to wastewater prior to its use as irrigation water in agriculture is the method that can produce an effluent that meets the microbiological and chemical quality standards with minimum operating and maintenance requirements. The adoption of a lower level of wastewater treatment is desirable especially in developing countries, both because of the cost and the difficulty of reliably operating the complex wastewater treatment systems [14].

In designing of wastewater treatment plants, consideration is given to the need to reduce the organic load and suspended solids, and to limit environmental pollution. Elimination of pathogens is rarely taken into account, but if it is desired to use the effluents in agriculture, this should be the main objective, and processes should be selected and designed accordingly. Wastewater treatment to remove those constituents that may be harmful to plants and to human and animal health is technically possible and can be economically feasible.

Unfortunately, very little information on wastewater treatment plants is available in developing countries and the available data does not include the microbiological and phisico-chemical qualitative parameters of effluents, which are important for the safe use as irrigation water [14].

Agro-zootechnical and livestock farms, especially cow farms, generate large amounts of wastewater, which are difficult to handle due to their complexity. The main organic pollutants encountered in the wastewaters from cows are carbohydrates, proteins and fats from milk. Wastewater from cow farms also contains high suspended solids, high COD, high BOD, heavy metals, large amounts of nitrogen, phosphorus, antibiotics, and pathogenic bacteria (*E. coli*, yeasts, molds, coliform bacteria, *Staphylococcus aureus* etc) which make them toxic if not properly handled.

Wastewater causes significant threats to surface and groundwater which would endanger our drinking water resource, causing the pollution of groundwater. This kind of wastewater treatment can achieve good treatment effect by combining biochemical and physicochemical methods. If for food crops there should be specific regulations on the reuse of wastewater, treated or non-treated, there is a category of crop less subjected to the risk of pathogens contamination with fewer consequences on human health: the energetic crops.

Using wastewater to irrigate energetic crops after proper preliminary treatment has several advantages and the high nutritional content of wastewater can result in economic growth. On the other hand, energetic crops have gained the interest of national authorities which encourage the use of heating sources based on biomass and the development of biogas production and distribution systems at community level.

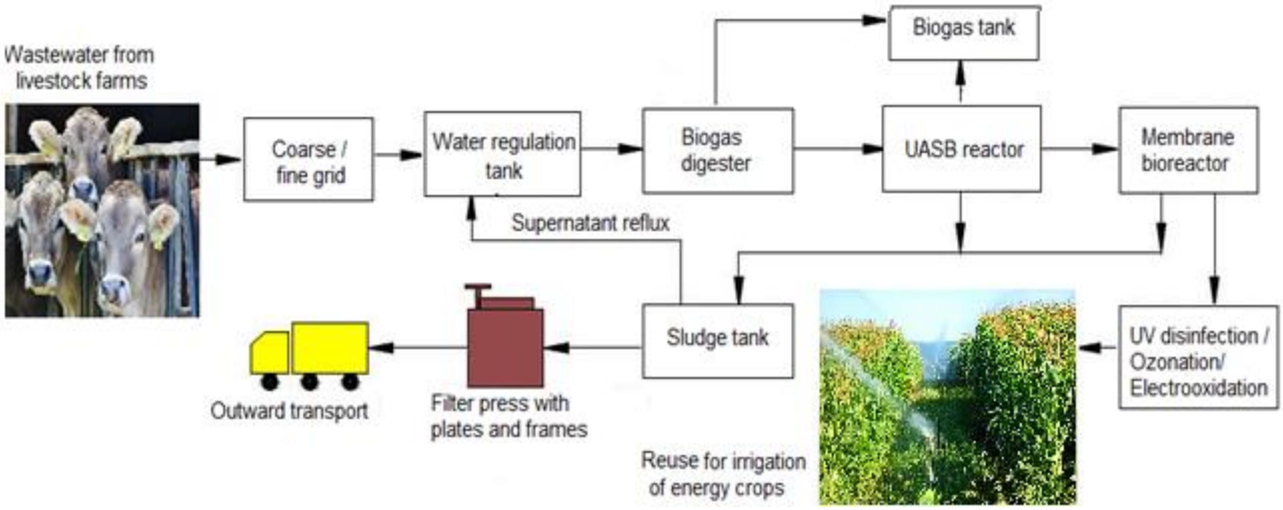

Fig. 3. Possible treatment process of wastewater from livestock farms [adapted, 17]

RESULTS AND DISCUSSIONS

It is estimated that at least 10% of the global population consumes food from irrigation with wastewater and over 20 million hectares (10% of all irrigated land) are irrigated with untreated, partially treated / diluted or treated wastewater. 200 million farmers in 44 countries recover over 15 million m^3 of treated wastewater / day for irrigation [10]. Actual reuse of treated wastewater is limited in developed and developing countries.

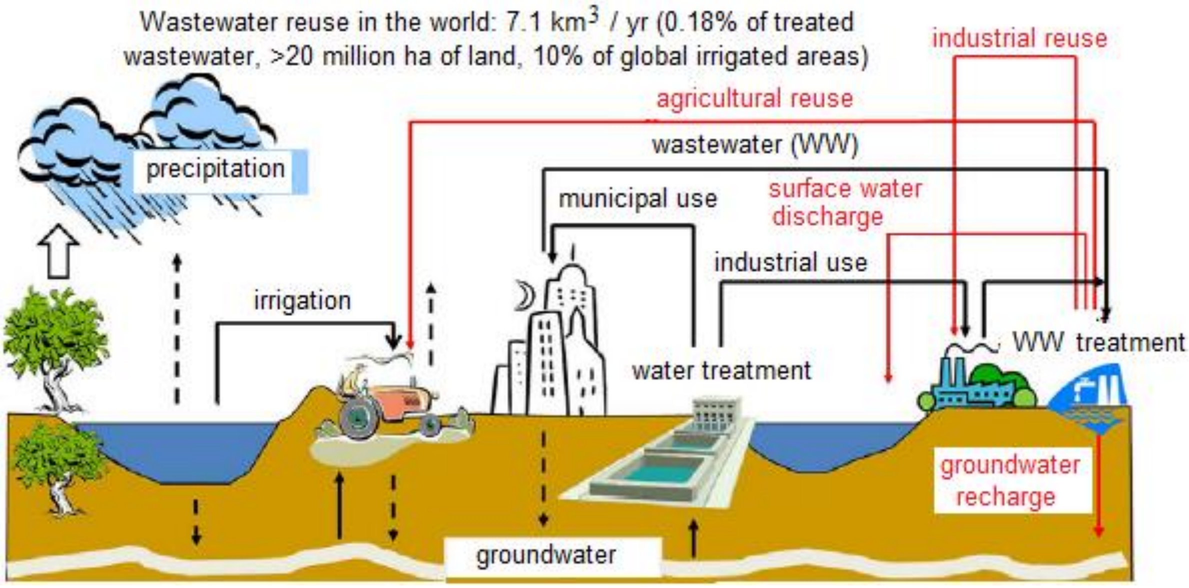

Fig. 4. Wastewater reuse and the hydrologic cycle [13]

Although in developed countries, especially in large cities, wastewater is treated, its rate of reuse is low and most of the treated wastewater is released into natural receptors. This is partly because most developed countries have relatively abundant water resources, and wastewater treatment is mainly driven by concerns on environmental protection. Economic gains of wastewater reuse are relatively less significant, especially in Central and Northern European countries. In developing countries the wastewater treatment rate is low and a high percentage of wastewater from industries and households is discharged without being treated [12].

However, many countries have included the reuse of wastewater as an important dimension of water resource planning. In the arid areas of Australia and the US, wastewater is intensely used in agriculture, which increases the availability of high-quality drinking water [14]. Wastewater recycling / reuse is increasing in Australia, where it is estimated a total of 166.2 billion l / yr. In the US, the practice of recycling / reuse of wastewater is a vast and growing industry, with statistical data showing that around 9.84 billion l / day are reused for irrigation of golf grounds, lawns, for irrigation of edible crops, for industrial use (cooling) as well as for the recharging of groundwater sources [7].

Several Latin American countries report large irrigated areas with both treated and untreated wastewater. In Colombia, despite the abundant water resources, irrigation with treated or raw (un-treated) wastewater is practiced on almost 37% of the total irrigated area [4].

Table 1

Data on the use of wastewater in agriculture in Latin America [**4**]

Country	Surface irrigated with wastewater [ha]		Agricultural crops	Type of treatment plant
	treated	untreated		
Argentina	>3000	20000	vegetables, vineyards, pastures, forests, olive orchards and fruit trees	stabilization pond
Bolivia	unknown	5700	potatoes, corn, vegetables, grass, vineyards	stabilization pond, Imhoff decanter
Chile	unknown	130000	vegetables, vineyards, cereals, fruit trees	activated sludge, aerated lagoons
Colombia	330000	>900000	rice, vegetables, pastures, tobacco, corn, fruit trees	activated sludge, aerated lagoon, anaerobic reactor with up-flow sludge bed, biofilter
Dominican Republic	500	unknown	rice, corn, vegetables, fodder	activated sludge, aerated lagoon, anaerobic reactor with up-flow sludge bed
Ecuador	80	unknown	corn, tomatoes, pepper, cucumbers, melons	stabilization pond
Mexico	70000	190000	cereals, fodder, fruit trees, vegetables	activated sludge, stabilization pond, anaerobic reactor with up-flow sludge bed
Nicaragua	250	unknown	bananas, forage maize, fodder, sugar beet, vegetables	stabilization pond, Imhoff decanter
Peru	4000	16000	vegetables, fodder, cotton, fruit trees, aromatic herbs	stabilization pond, aerated lagoon, biofilter, activated sludge

In northern Argentina, for over 40 years, vineyards and other crops have been irrigated with wastewater. In many Caribbean islands, including Cuba and the Dominican Republic, wastewater is usually recovered in hotels for gardening and / or irrigation of urban green areas or for irrigation of sugar cane crops [4].

In China, wastewater has been used to irrigate crops for over 50 years.

Most of the wastewater treated in the treatment plants is discharged into rivers that provide water for agriculture. At present, more than 3.3 million ha of arable land is currently irrigated with domestic or industrial wastewater [3]. In 2010, 59.3% of the waste water treated in Beijing's treatment plants was reused and thus reduced the freshwater extraction by 19.3%. An increase of 17.6% in reuse of waste water by 2020 is planned in Beijing compared to 2004 [6].

Jordan is considered one of the ten poorest countries in the world in terms of water resources and reuses the treated wastewater for irrigation for over 30 years as a way to overcome water scarcity. Secondary effluents of Jordan's largest wastewater treatment plant (WTP), As-Samra, are wholly utilized to irrigate crops of citrus, vegetables, bananas, grapes in the Jordan Valley. Jordan's wastewater has high salinity due to the high salinity of drinking water, but has a low content of heavy metals and toxic organic compounds, due to the low level of industrial discharges in the WTP [1].

The Hashemite Kingdom of Jordan and the Kingdom of Saudi Arabia have a national policy on the full reuse of wastewater effluents and have already made considerable progress in this regard. In China, the use of wastewater and sewage sludge has been adopted since 1958 and nowadays 1.33 million hectares are irrigated with sewage effluents. There is unanimously accepted that the reuse of wastewater is justified by agronomic and economic reasons, and that measures must be taken to minimize the potential adverse health and environmental impacts [14].

At present, at least 11% of the European population faces water stress and in order to keep this deficit under control, the reuse of municipal treated wastewater in Europe should increase more than twice in 2025 as compared to 2000 [6]. South Europe is one of the areas where water scarcity is expected to grow in the future. In this region, 4 out of 15 countries have already adopted regulations on the reuse of wastewater (Greece, Italy, Portugal and Spain).

The United Nations Organization has declared that by 2050 most Mediterranean countries will have less freshwater availability than in 1990. In Mediterranean countries, treated wastewater is increasingly used in water scarce areas, and their application in agriculture is becoming a valuable asset. Israel is the pioneer in the reuse of wastewater, as about 73% of treated wastewater is reused and most of it is used in agriculture [6]. In Israel, in 2010, 45% of the water used to irrigate the agricultural land came from recovered wastewater. In addition, over 60% of urban wastewater is recovered for use in agriculture, and in 2015 it was reached the objective of 100% reuse [8].

In Greece, treated wastewater is used to irrigate vegetable crops and lemon orchards, and future prospects favor such reuse, but to achieve full social acceptance, efforts are still needed to reduce the health risk factor [9]. Cyprus and Malta are the most active EU member states in this area, with nearly 100% and respectively 60% of the treated wastewater being reused in 2006. However, at EU level, this percentage is 2.4 or 0.5% of annual freshwater abstraction [6].

Romania is relatively poor in water resources, with only 1870 m^3 of water / inhabitant / year compared to the average of 4000 m^3 of water per inhabitant per year in Europe. In 2014, Romania's water requirements were 7.21 billion m^3 / year. According to Eurostat, in 2013 the water exploitation index was 15.2%, below the 20% threshold for water stress on Member States. A significant part of Romania's agricultural area is already experiencing the negative effects of drought and deficient irrigation systems. The total irrigated area in Romania is 2.99 million hectares, of which 85% uses Danube water. Between

2011 and 2015, the surface of irrigated soil in Romania accounted for less than 300,000 ha (1%) of the total arable land, consuming about 1 million m^3 of water / year. Romania's accession to the European Union requires compliance with European requirements, and the reuse of wastewater effluents is in line with Objective 6 of the European Union's Sustainable Development Strategy. In Romania, the reuse of wastewater in irrigation is not widely practiced (there is a low demand for the global use of treated wastewater) [10].

In Romania, different methods of wastewater treatment for agricultural reuse are addressed only at the experimental level. Although the Romanian legislation does not prohibit the use of irrigation water, the relatively low number of users connected to the irrigation system does not stimulate investments in new wastewater treatment technologies to use as irrigation water. However, in the long run, interest in the reuse of wastewater as irrigation water could increase as Romanian agriculture continues to be dependent on climatic factors [10]. In many agricultural areas where there is a water shortage for irrigation, in livestock farms, large amounts of wastewater are collected (a mix of domestic wastewater produced on the farm, wastewater from milk processing plants, wastewater from paddock washing, liquid cattle manure and meteoric waters). There are still micro-farms and farms that do not have a wastewater treatment system and they either evacuate the wastewater in the sewerage system of the locality (if it exists) or discharge it directly to river or natural water body. Other farmers collect the wastewater in sedimentation basins or in lagoons, and further scatter it on the farmland without taking into account the potential risks due to pathogens in wastewater.

Recent developments in technology and changes in attitudes toward wastewater reuse suggest that there is a potential for wastewater reuse in agriculture.

CONCLUSIONS

Increased water needs makes the use of effluents (treated wastewater) an effective solution to solve the problem of water scarcity, to save significant quantities of drinking water, to reduce the use of chemical fertilizers (nutrients in the wastewater can replace conventional fertilizers), thereby protecting the environment and improving crop yield.

As a result of increasing global water scarcity, farmers in many arid and semiarid areas must find solutions to irrigate their crops, so they often must use treated, untreated or undiluted wastewater which is cheaper than other water sources.

In agriculture, special attention must be paid to ensure the safe use of wastewater to irrigate vegetable crops, mainly because of the potential chemical and microbiological contamination.

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