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PURIFIED SEWAGE AS AN ALTERNATIVE SOURCE OF WATER

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Abstract

Water scarcity is one of the biggest global problems affecting all societies in the 21st century. Climate change has already been acknowledged by most of the world's scientific community and found that it's primarily caused by the greenhouse gas emissions from human activities, industrial activity, motorized transport, industrial agriculture. The consequence of the climate change is the more acute water cycle, the change in evaporation conditions, which is further strengthened by change of the surface (change of plant cover, change in the ratio of enclosed or built-up areas, drainage of surface water, etc.) and direct heat emission of buildings, plants, vehicles, etc. in built-up areas. The growing population and the changing climate result water demand increase. This fact, and the limited access to water, plus the fierce competition for water sources, have created the need for today's so-called "non-traditional" sources of water, like low-yielding wells and springs, rain water, rainfall precipitation, urban rainwater and that's why waste water recycling should be also considered in water management. The reuse of purified sewage is an important and cost-effective element of water scarcity, an option to counter water scarcity. The purpose of the study is to provide a practical example of waste water recycling in various use cases that will help countries with fresh water shortage or countries in favour of environment friendly policies to reduce water shortage and water abstractions.

Keywords: *climate change, sustainable water management, water demand, wastewater recycling*

1. INTRODUCTION

Water is an indispensable for life, but despite of the significant water resources available, persistent and severe water shortage prevails in many regions of the world. The reason is that potential water resources are distributed unevenly in both space and time, water supply maturity is low and water resources available are inadequate.

Water scarcity will worsen due to unsustainable use and management of the resources as well as the climate change.

The forecasts show a significant increase in water demand between 2000 and 2050. (Figure1) Demands are expected to grow mostly in the manufacturing industry by about 400%, in electric energy by 140% and in household consumption by 130%. [1.]

Due to the increased demand in other areas, agriculture is expected to get less water, which is augmented by the fact that around 3.9 billion people, more than 40% of the population of the earth, will live in drought-stricken territories by then. [1.] Population of these areas will face agricultural and food security problems.

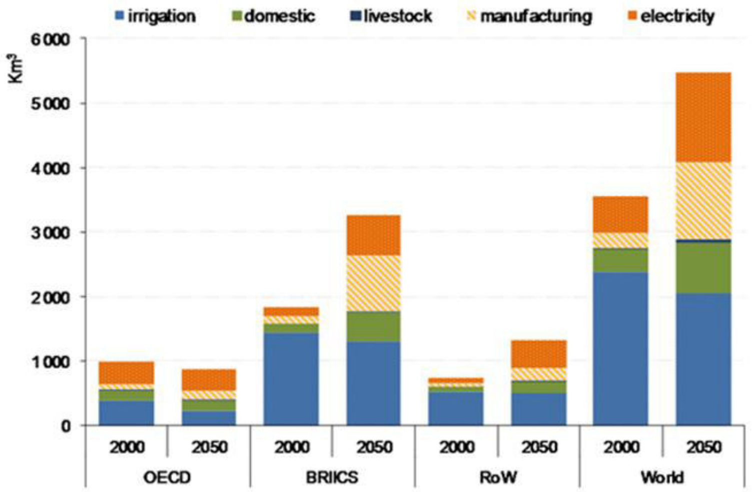


Figure 1: Global water demand: Baseline scenario, 2000 and 2050. [1.]

Climate change will make the growth of water demands even more significant. The climate of the Earth has also changed in the history, but the changes were still natural and had taken place over a long period of time. With the developing industry, use of fossil fuels has been multiplied and over the last 150 years, atmospheric carbon dioxide concentration has increased by 33%, [2.] resulting increase in the surface temperature too.

Climate models predict that between 2021 and 2050 the biggest change in temperature is expected in summer when the temperature increase may reach 2 ° C and may exceed 3.5°C by the end of the century. In southern and eastern territories higher temperature increase are expected. The frequency of warm extremes increases heavily, and the occurrence of cold extremities decreases slightly. [3.] Temperature increase makes water circulation more intense (evaporation, precipitation, leaching, infiltration / drainage). The average rainfall is expected to be 3.9% higher than in the period 1961-1990 [2.].

The potential impacts of climate change on waterways are presented in Table 1.

In longer dry periods due to climate change the decreasing precipitation rate has a negative effect on water resources, which results in less water available and can also lead to deterioration in water quality.

Table 1: Climate change and water management contexts [4.]

Weather	Regime
Warming	Increasing water temperature, falling ice levels, increasing evaporation
Increase in aridity	Declining annual drainage, decreasing useful surface and underground water resources, deteriorating water flow
Melting glaciers	Change in the course of Danube during the year
Rearrange of precipitation	The runoff is growing in winter, larger rivers suffer from uncertain flood waves
Great rainfall	More common and intense flash flood
Dry periods	More frequent, more extensive drought

Considering all these factors, finding and developing alternative water supplies is becoming increasingly important today. The solution can be recycling of purified sewage and rainwater to the most extent, and the implementation of circular farming.

"Well purified" sewage (new water) is not just an "alternative water resource", but a positive regional water management element, which is particularly important in drought and water scarcity areas, and its benefits must be exploited. Sewage can serve not only as a soil supporter, but it can also complement the missing moisture content. The water "extracted" at high cost shouldn't be disposed after use but must be retained and utilized sensibly [5].

The purpose of this study is to present practical solutions that contribute to implementation of integrated water management through treated sewage recycling.

2. EXAMPLES OF WASTEWATER RECYCLING

During recycling, the recoverable materials contained in the purified wastewater and the water itself are reused.

This can be done directly when the purified sewage from the wastewater treatment plant is introduced straight into the distribution system or indirectly, when purified sewage from the wastewater treatment plant flows into a watercourse, pond, reservoir, etc. and will be used later. Use of sewage is possible in the following areas ensuring the preservation and replacement of water resources [6]:

- production of drinking water with high efficiency cleaning, direct or indirect technology
- filling the aquifer, the production of drinking water with recharge of an aquifer
- using non-drinking water quality in agriculture, industry and urban environments,
- with agricultural, energetic utilization of sewage sludge from sewage purification.

Growing population and associated urbanization, especially in developing countries, are new water management challenges. Increasing water use and, therefore, pressure on existing water resources are urging reuse of water, especially in countries where there are limited resources available or apply stock-friendly environment policy.

Utilization of industrial sewage through the cooling process more and more widespread, and some industries (e.g. paper industry, thermal power plants) can recycle used technological waters into manufacturing processes to the largest degree. Circular water management is already the most effective method in this area. However, industrial recycling from purified communal sewage is only 6-15% worldwide, but the annual growth rate is 15-20%. [6].

Urban sewage utilization is mainly applied to irrigation of parks, golf courses and gardens with purified sewage, and to a small extent it provides alternative water use in toilet flushing. Environmental and recreational wastewater recycling can be achieved by creating artificial lakes and filling natural lakes with rich and aesthetic landscapes.

The use of purified sewage from communal sewage treatment plants as an increasing source of water is evidenced by the fact that in the United States the amount of recycled purified communal sewage is increased by 15% [7].

The amount of recovered and recycled water has been increasing worldwide over the past two decades. Today, 3700 wastewater recycling plants operate in the world, producing a total of 19 million m3 of water per year for different uses [8]. In some countries it's no longer visible only in irrigation, but also in the production of indirect or direct drinking water.

During recycling, the most important aspect is to exactly specify quality requirements for sewage and make everyone being compliant with them, thus ensuring the protection of human health, soil, plants, and groundwater. Only having realized all of these we can expect favourable public acceptance. To do this, it is necessary to develop a comprehensive regulatory system and limit values for recycling.

2.1. Recycling for drinking water

Reuse of sewage can be done indirectly or directly for drinking water production. Utilization as indirect drinking water is the oldest practice in countries, where wastewater is brought to the drinking water system, after extraction and purification to drinking water quality from the natural recipient (streams, rivers, groundwater).

However, the main purpose of this technology is not the utilization of wastewater, but the disposal of waste water after cleaning. The first technology for drinking water was established in Los Angeles, in 1962, where the main purpose was not to place sewage, but to use it after purification [6]. Ground water enrichment improves groundwater resources by utilizing natural cleaning processes in the soil, prevents or reduces the compaction of aquifers, prevents salt water from entering the coasts, and provides additional pre-use treatment. Soil Aquifer Treatment (SAT) is used to leak through the soil to the aquifer.

2.1.1. Indirect drinking water production with Soil Aquifer Treatment technology

The technology allows groundwater replenishment through the soil to allow reuse of water. The method has been developed in the US and has been applied in many parts of the world. The pre-treated waste water is leaked into the aquifer (Figure 2) and by adsorption, ion exchange and bacterial degradation in soil, the concentration of contaminants during filtration and biodegradation decreases [9].

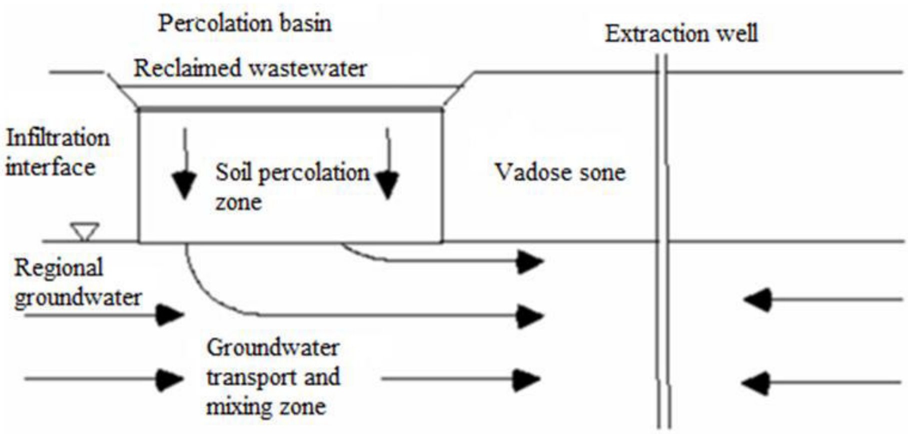


Figure 2: Soil Aquifer Treatment technology [9]

The disadvantage of this technology is that a clogged, contaminated layer appears relatively soon on the surface of the filter layer due to splicing, which prevents further infiltration.ng. During cleaning, the removal of organic compounds is the most effective; it depends on the residence time, the leakage path and the pre-treatment concentration.

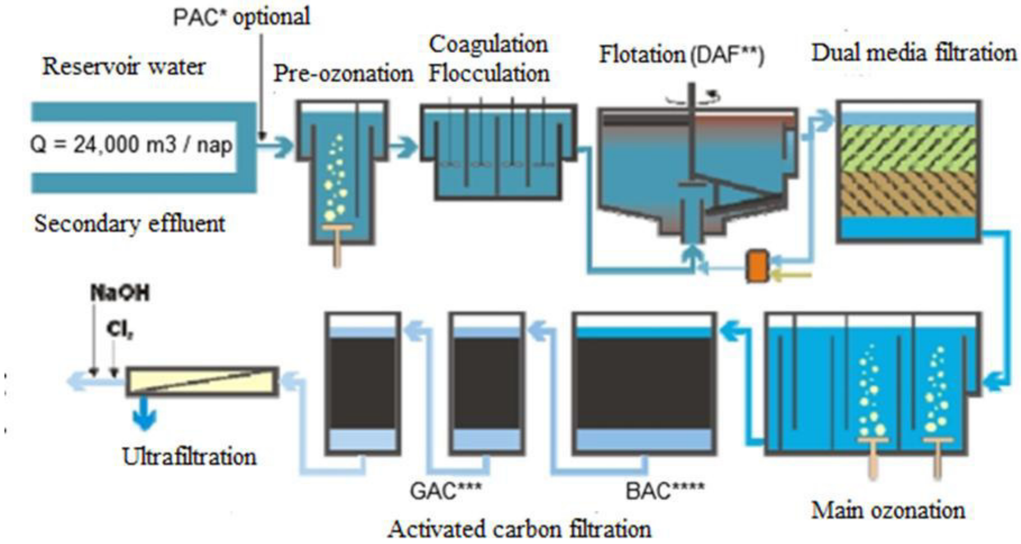
The removal efficiency of organic materials increases by the residence time and the depth, as there is enough time and water path for chemical, physical and biological processes. To make this happen, good quality soil with good.

2.1.2. Drinking water production by direct method from purified communal sewage

NGWRP (New Goreangab Water Reclamation Plant) technology is used to produce direct drinking water e.g. in Windhoek, Namibia, where drinking water is produced using purified sewage due to scarcity of water resources. It takes about 25% of total urban drinking water [10]. The technology operated by a consortium of Vivendi Water Systems, Berliner Wasser and Wabag produces 24,000 m3 of drinking water per day, combining sewage water and reservoir water in 50-50 % proportion.

Proper water quality is ensured by multiple ozone treatment, coagulation, sand filtration, ultrafiltration, activated carbon treatment and disinfection. (Figure 3)

Ultrafiltration and disinfection are highlighted in the technology, these steps make possible to remove the components dangerous to human health with the greatest efficiency. We can remove one of the most resistant pathogenic agents, Cryptosporidium with this technology by means of ozone, coagulation, dissolved oxygen intake, double sand filtration through ultrafiltration and chlorine disinfection processes [10].



*PAC: powdered activated carbon, **DAF: dissolved air flotation, ***GAC: granulated activated carbon , ****BAC: biological activated carbon

Figure 3: NGWRP process flow diagram [10]

2.2. Replenishment of water resources with purified sewage

Similarly to the indirect drinking water production, groundwater supply, seaside saltwater inrush control, seasonal stocking can utilize by pre-treated sewage into the soil by leakage. The technology is based on natural self-cleaning ability of the soil [11].

During leakage, a large part of the water content is taken up by the plants, evaporated, and the non-recoverable parts reach the groundwater. Organic substances are oxidized, transformed into inorganic materials, nitrogen compounds are utilized as nutrients by the plants and the remainders degrade. However, decomposition products may become hazardous, so it is important to regulate the process and implement pre-recovery treatment. The trace elements and bacteria are screened with great efficiency, but the same is not valid for viruses. Therefore, disinfection is an important technological step in pre-treatment.

2.3. Utilization of sewage in agriculture

The origin of agricultural utilization of sewage goes back to times, when the precipitation and sewage of the settlements were consciously collected and channelled. The technology created this way was called sewage drainage, the purpose of that was clearly utilization. Today, however, it is more appropriate to talk about agricultural landfilling and utilization of sewage, since its purpose is not primarily recovery but rather cleaning and placement [12].

During the agricultural utilization process, purifying of sewage is a productive process in which renewable energy sources (solar energy, soil organisms) provide the necessary energy for the decommissioning process and at the same time return biomass materials to natural circulation.

The purification process takes place in the soil ecosystem, as a result of the degradation processes, the water is purified, some evaporates through the evapotranspiration, the other part is incorporated into the plants, stored in the soil and, through the soil, infiltrated into the groundwater, water circulation [13]. The most ancient natural cleaning on the ground for millennia. Pollutants are adsorbed on the surface of soil particles and pores, microorganisms convert organic pollutants into inorganic nutrients, and they are utilized in plant capture.

Municipal wastewaters are suitable for sewerage, that requires strict public health standards and compliance with them, particularly because of their pathogenic agents.

Industrial waste water is suitable for agricultural use only, if it contains mainly pollutants of natural origin and organic substances, but no toxic substances or only the amount below the permitted limit value. E.g. sewage effluents from food industries like sugar, starch, spirits, beer, cereals, dairy production and canning. They can be used well in some sectors of the light industry, e.g. hemp, lencing, paper, pulp and wood industries.

From the chemical industry the wastewater produced in the fertilizer production can be utilized in agriculture, since it is practically diluted fertilizers. Cooling waters from the energy industry and construction industry wastewaters still meet the quality requirements of usability.

In the wastewater produced by agriculture there are many useful nutrients, for example in sewage sludge, but there may also be many substances that make their use limited. Wastewater from agriculture cannot be utilized if it contains poisonous or radiant substances more than the permitted limit values that originate from plants that process infectious diseases or animal products.

During the complex disposal and utilization of sewage, we use the self-purifying ability of the ecological system. To make this process happen in specified soil, soil layers and time are required, because in the absence of any of them, the groundwater is contaminated with age-destroying microorganisms and undegraded organic materials. Soils are capable of physical filtration, biological transformation and chemical processes, of course, up to a certain level of load.

The end products of the self-cleaning process are the different inorganic salts and humus. From the soil point of view, the suitability of sewage for irrigation is determined by its toxic content and the concentration of all dissolved salts.

The latter is important because the increase in the salt content of the soil can lead to salinization. Central and lighter loam soils are the most suitable for sewage drainage [14]

They can accommodate relatively large amount of water and their adsorption capacity is adequate.

Better quality sand soils are also suitable for filtering large amount of wastewater, but their adsorption capacity is low, therefore their cleaning capacity is lower. According to the EU Water Recycling Guide, sand and sandy soils are the best for wastewater utilization. It is not recommended to use purified sewage for irrigation purposes in areas heavily or moderately affected by inland waters [15].

Purified sewage is a valuable source of growth in plants, containing water, nutrients and organic substances in the appropriate composition. Therefore, to assess its possible utilization it is important to examine how the nutrition and water balance of a given area would be affected.

The following options are available for irrigation utilizing the liquid phase of purified pre-treated waste water:

- reed, grassland,
- forestry (e.g. poplar plantation) and natural vegetation,
- special tree plantations (e.g. energy plantation)
- in areas under field cultivation, with different irrigation methods,
- in vineyards and orchards.

Tree plantation (poplar, willow) sewage treatment and disposal sites are, the most suitable for treating waste water economically and environmentally based on the experience. Utilization on energy plants (crown-post, chainsaw, energy grass, etc) primarily serves the production of biomass for wood plantation supplemented by water and vegetable nutrition.

Additionally, the disposal of prepared, good quality waste water after soil purification can be used to supply water (and partly nutrition) for perennials and one-year crops. Cultivated crops are like e.g. corn, sugar beet, sunflower, seed. In this case, the collection and temporary storage of the sewage outside of the irrigation season must be also solved.

In case of field utilization, it should be prepared that in some parts of the area permanent vegetation, i.e. tree plantation, is necessary for those periods when the crop rotation does not allow field placement.

The environmental, climatic and soil conditions, plus the economic structure of Hungary give us the opportunity to utilize biomass to a high extent, cultivation of energy crops can supply materials for production.

Increasing the yield of energy crops by exploiting the ability of these plants to absorb high levels of nutrients and, therefore, to produce large-scale biomass, is a wastewater disposal opportunity. The limiting factors of the large-scale biomass production of woody plants are the soil nutrient supply and precipitation at about 80% of Hungary's territory. About two-third of the country has regular summer droughts, when a lack of water is clearly a limiting factor, so then the unclean or partially purified sewage can play important role. Tree plantations, such as crop cultivations, are beneficial because they can take a greater load and can be irrigated throughout the year.

The energy tree plantation is the plantation where trees are planted for energy tree production. It is important that the forest law is not applicable to energy tree plantations.

Plantations are created in flat or hilly areas, in good quality sites, where large-scale production is possible, and landscape allows machine harvesting (combinable area) [16]. Thus, this variant of tree plantation cleaning has dual purpose, on the one hand, the natural cleaning and disposal of sewage, on the other hand the production of biomass with significant energy efficiency.

The water and plant nutrients supply to the tree plantation is provided by the waste water. The most common trees plantations are poplar and willow, which create the possibility of irrigation with sewage water by drought or rainwater-like irrigation. Essential aspects of establishing plantations: the assessment of environmental impact, the energy balance and the specific energy price.

Research is nowadays under way for Chinese reed species (Miscanthus spp.), the results so far show that they are the most productive plants in Europe [17]. In the areas taken off from agricultural utilization, energy wood plantations can be established with fast growing species of trees, whose growth can be controlled by adequate nutrient intake.

SUMMARY

Problems arising globally in water supply, population growth, urbanization, climate change and the wasteful use of inventories are increasingly urging to develop and apply technologies that can mitigate water scarcity and reduce the amount of water exploited.

Since clean water is limited in nature, wastewater recycling can be a solution to the production of sufficient drinking water and use water. Modern sewage treatment technologies can help to solve these problems. Their purpose is to hold the detrimental solutes and solids in the effluent economically so that they do not jeopardize the ecological conditions of the water bases and the environment, especially conditions of the intaking water bodies. The emphasized aspect of sustainable water management is the greater recyclability and energy utilization of retained materials. Thus, a sewage management process is implemented that protects and assists in preserving human health, does not harm the environment, does not absorb natural resources, has a proper technical and institutional background, economically viable and socially accepted. The liquid phase of purified sewage can provide opportunities for countries with fresh water shortages to seemingly expand their freshwater resources. It also provides a favourable alternative to advanced, environment friendly policy, considering that the largest water user is agriculture, so the amount of water extracted and used in the field of irrigation can be effectively reduced. At present, due to healthcare reasons it is more accepted socially the use in the production of less risky energy crops, which can be further developed and made more versatile in the future with adequate regulation.

Climate change poses a new challenge to water management, which also plays an important role in recycling waste water through which the effects of drought can be mitigated, and water retention can be solved by maintaining water.

The three most important functions of modern sewage management and sewage treatment are the protection of public health, the re-circulation of plant nutrients and the protection against environmental degradation, which are now required to meet high quality technology. This is important primarily because society can no longer miss the used water recycling, but responsibility to maintain water quality is left to the society.

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