DEVELOPMENT OF MODULAR WATER TREATMENT EQUIPMENT BASED ON MBR TECHNOLOGY FOR THE TREATMENT OF MEAT PROCESSING INDUSTRY WASTEWATER

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Abstract

Due to its high decomposition efficiency and its compact size, the MBR (Membrane Bioreactor) wastewater treatment technology plays growing role in the treatment of wastewaters highly contaminated with organic material. The membrane bioreactor is a combination of a bioreactor and a membrane filtering technology, and which can operate continuously. The goal of our project is to create a new MBR technology with high reliability and a wastewater treatment equipment, based on the aforementioned technology that can be built in an ISO container, with minimal need for space and that has particularly high efficiency of decomposition. The innovation in this technology is that it will operate using extremely low transmembrane pressure (flux being circa 35 L/m^2/h) to allow for the long-term operation of it, with low maintenance need and without fouling. Usage of low pressure and large specific membrane surface further enables the production of an energy-efficient device. According to the preliminary studies, this new MBR based technology developed for meat industry wastewater treatment will have an energy demand lower than 0.55 kWh/m^3.

Keywords: sustainable development, water reuse, membrane technology

Introduction

The total water resources available to us are considerable, because water from neighbouring countries flows into the Carpathian Basin, but our renewable water resources, which are fed by rainfall falling on the territory of the country, are very poor. On top of this, our net water balance is negative, meaning that we are releasing more water than is entering the country. This means that we are consuming a significant amount of our slowly renewing aquifers, but at the same time we are not retaining rainwater run-off and tidal flows from rivers. Every year, more than three Lake Balaton volumes of freshwater are discharged from the country, mainly through the Danube water system. We do this despite knowing that 95% of the quantity and quality of our rivers depends on the goodwill of our neighbours. About 90% of annual precipitation falls in about 70 days, meaning that for almost 300 days of the year there is no significant rainfall. The winter precipitation is hardly used because it is not taken up by the vegetation. In the lowlands, evaporation could be 800 mm, but only 500 mm of

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precipitation falls. The difference is made up primarily by groundwater, with a second series of river irrigation. In addition, much of the industrial and domestic water supply is also based on groundwater. The greatest water demand occurs when there is the least water available (summer drought). We retain little water because of urban concrete pavements and intensively ploughed farmland that is left uncovered all year round, when the best water bank could be the soil itself.

Water recycling practices to be implemented as soon as possible (in-line systems)

Current practices, which are seriously wasteful, need to be changed and, where possible, the supply of water for industrial processes should be recycled through the reuse of biologically treated wastewater. Such interconnected systems result in significant water savings and protect our natural water resources. Of course, treated municipal wastewater requires some 'tertiary' treatment before it can be further recycled. For irrigation and natural water recharge, a different type of further treatment is needed than for industrial water supply. The water needs of industry are also different, with different water qualities required for each industry. It is important to stress, however, that industrial water supplies are still equipped in the vast majority of cases with specific water treatment plants, which can treat pre-treated municipal wastewater with additions.

Recommendation for water use practices that can be implemented in the short term

In this system, raw water of natural origin is only purchased by waterworks for domestic use only, and the biologically treated wastewater is then transferred to the industry after tertiary treatment. The industry further treats and uses it according to its own needs and then releases it after purification. As shown in the Figure 1, the number of water and wastewater treatment systems does not decrease in this interconnection, and even increases somewhat in complexity due to tertiary treatment, but the interconnected system significantly reduces the extraction of raw water from the natural environment.

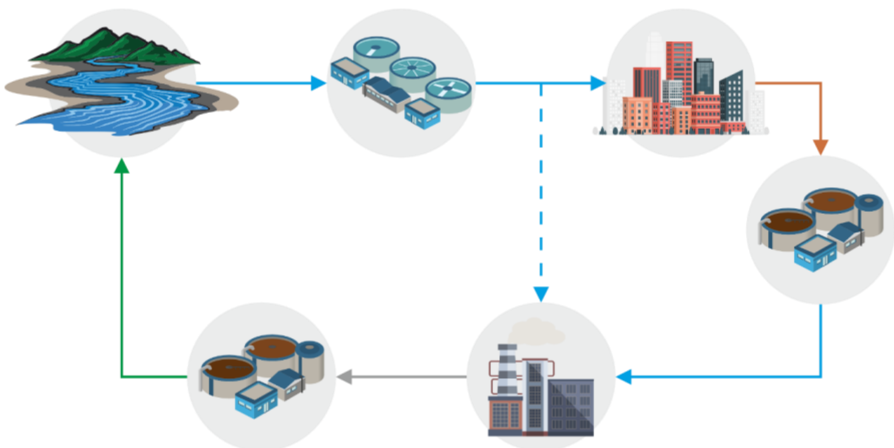

Fig. 1 Recommendation for water use practices that can be implemented in the short term

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Proposal for a longer-term, in-line water use practice based on full industrial waste water recycling

This practice can be seen as an improvement on the previous system (Figure 2.). In addition to linking municipal water treatment systems to industrial water supplies, industrial companies recycle all their waste water (ZLD - zero liquid discharge). This means that the water consumption of industry is covered exclusively by municipal treated water to compensate for evaporation losses and product absorption losses.

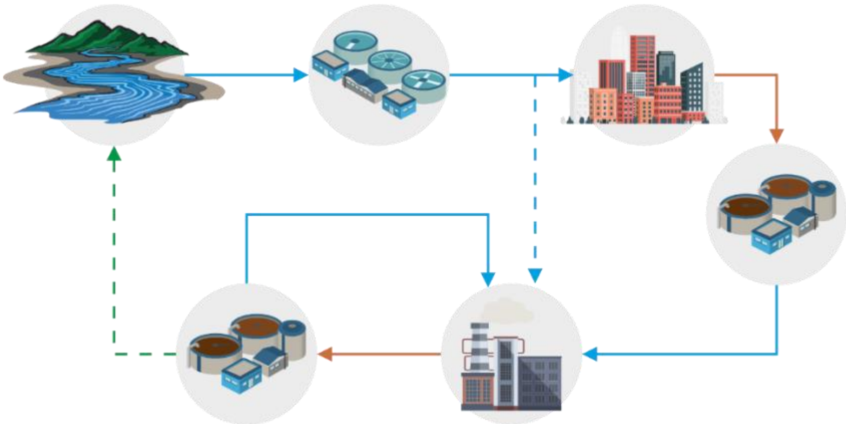

Fig. 2 Proposal for a longer-term, in-line water use practice based on full industrial waste water recycling

What is treated municipal wastewater?

The Table 1. below shows the most important water quality values for treated wastewater in current Hungarian practice and the water quality acceptable for agriculture and industry. The values per treatment plant can vary greatly depending on the water quality category to which the plant is treating. From the data in the Table 1. it is clear that for both industrial and agricultural uses there is a common intersection for most values where virtually no further treatment is needed. In all cases, however, the bottleneck is the level of microbiological contamination and the concentration of fats and oils. In addition, it may be necessary to reduce the organic matter content, the suspended solids content and the total salinity, depending on the case. The above-mentioned parameters, i.e. the reduction of suspended solids, organic matter, oil and fat content and microbiological contamination, are not necessarily the primary requirements on the consumer side, but they are also requirements to be taken into account for the transport and treatment of purified water as a raw material. The need to reduce the salt content and concentration of certain elements may vary from case to case.

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Table 1. Water quality values for treated wastewater in Hungary

Parameters	Treated waste water	Agriculture	Industry
pH	6.5 – 8.8	6.5 – 8.8	6.5 – 8.8
Turbidity NTU	1 - 30	<30	<200
Total suspended solids mg/l	35 - 200	<50	<100
Chemical oxygen demand COD_{cr} mgO_2/l	50 - 200	<90	<30
Biochemical oxygen demand BOD_5 mgO_2/l	15 - 50	<45	<10
Total nitrogen mg/l	20 - 55	<30	<30
Total phosphorus mg/l	0.7 - 10	<20	<1
Oil&Grease mg/l	2 - 10	<0.5	<0.5
Total salt content mg/l	500 - 2000	<450	<1000
Coliform number CFU/100 ml	$10 – 10^7$	<200	<200
Active chlorine mg/l	occasionally	<1	<1

Potential uses of treated municipal wastewater

The following are examples of how the world uses treated municipal wastewater:

1. Agricultural use as irrigation water, ecological water recharge for wetland rehabilitation.
2. Industrial use as feed water (mainly energy, chemical and petrochemical industries)
3. Use for drinking water

The first two are realistic alternatives in Hungary, with significant environmental and economic gains, while the third is often the only alternative in some areas of the world with severe water shortages, such as Windhoek, the capital of Namibia, and Singapore.

Agricultural usability as irrigation water, ecological water recharge

The agricultural use of treated municipal wastewater is basically irrigation, mainly for arable crops, possibly orchards and vineyards. The residual nutrient content of treated wastewater (organic matter, nitrogen, phosphorus, some trace elements) supports the nutrient supply to crops, reducing the need for fertiliser. Further reductions in the levels of certain nutrients may be necessary in the case of ecological water replenishment. Of course, as mentioned above, to prevent clogging of pipes and

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irrigation structures, it is necessary to reduce suspended solids, oil and grease and organic matter content and to reduce the number of germs to avoid the risk of microbiological contamination. Plant cultures cannot tolerate the active chlorine content, so traditional chlorine gas disinfection with bleach is out of the question. A specific need may be to reduce the Na-salt content to avoid salinisation, and to reduce the potential heavy metal content, which is not typical of municipal wastewater. Complex membrane technology can be used as a tertiary treatment to solve these problems.

Case study - Combined membrane technology treatment of municipal wastewater for irrigation water in Paros Island, Greece.

The collected biologically treated wastewater from the local wastewater treatment plant was further treated using a combined membrane technology system based on ultrafiltration designed and manufactured by Hidrofilt Ltd. This made the available 250 m^3/day of wastewater (Table 2.) reusable for agricultural purposes at a recovery rate of 80% (Figure 3.). The customer has been using the technology for two years now, mainly during the summer growing season.

Table 2 - Water quality data from the reuse technology of the biological treated wastewater on Paros Island.

	Treated waste water	Limits	Values
pH	7.36	6.5 – 7.6	7.1
Turbidity NTU	25	<2	<2
Total suspended solids mg/l	30	<2	<2
Biochemical oxygen demand BOD_5 mgO_2/l	25	<10	<8
Total nitrogen mg/l	8.86	-	4.13
Total phosphorus mg/l	1.48	-	1.48
E.Coli number CFU/100 ml	-	<2	<1
Total Coliform count CFU/100 ml	-	<20	5

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Fig. 3 The 250 m^3/day wastewater treatment system awaiting delivery

Biologically treated municipal wastewater as industrial raw material

The greatest potential of large municipal of treated effluents from large municipal wastewater treatment plants. Reasons for this are:

1. Concentrated large volume flows 10 000 - 100 000 m3/day.
2. The requirements for raw water are more relaxed than for irrigation. (microbiological cleanliness, presence of heavy metals, micropollutants are less important). Industrial use is also more acceptable to the population for psychological reasons.
3. Industrial plants usually already have a raw water purification system in place that can pre-treat incoming water (river, lake, well) for the specific process purpose. In addition, the so-called tap water quality is usually not sufficient for industrial plants, which have to further treat the water on their own, for example to soft water or desalinated water quality. These additional treatment costs are usually well above the costs of pre-treatment/water procurement.
4. For many plants, the quality of the water available in many cases barely exceeds the parameters of biologically treated water, e.g. flooded river water.
5. Appropriate legislation/permits can "encourage" companies to use treated wastewater.
6. Additional source of income for water utilities.

Technological implementation

In order to meet industrial feedwater needs, the biologically treated wastewater must be treated by tertiary treatment units. These units should be individually designed as part of a single technology, taking into account needs and possibilities. Generally speaking, it is membrane filtration equipment or a combination of membrane filtration equipment and possibly conventional processes. Membrane technology can be used to reduce germ count, organic matter and salinity. A key task is to retain

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organic matter and recycle it back into the biological treatment process without drastically increasing the salinity. On a small scale, a containerised version can accommodate up to around 200 m^3/day, while on a larger scale, an in-building design is preferable.

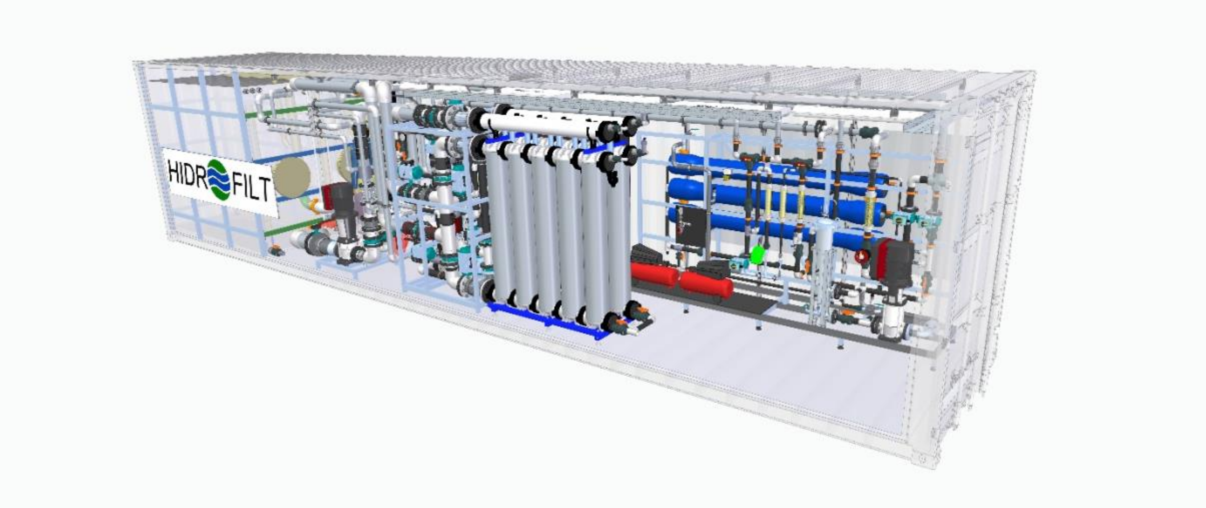

Fig. 4 Containerised wastewater treatment system 3D design

Development of a modular wastewater treatment plant based on MBR technology for the treatment of meat industry wastewater

The novelty of the technology developed is that it operates at extremely low transmembrane pressures, in order to allow the membranes to be used over the long term with low maintenance and without clogging. Due to the low transmembrane pressure and the large membrane surface area, the equipment is energy efficient. By using a novel membrane arrangement that allows multiple permselective microfiltration membranes to be operated in parallel in series, we have achieved the best energy-efficient LPMBR technology design by using an ultra-large membrane area ultrafiltration membrane with the highest energy efficiency. A new prototype product using innovative technology has been created by integrating a minimum energy demand circulation system, LPMBR membrane structure and bioreactor. By using the technology and equipment resulting from the project, meat processing companies will be able to modernise their existing water treatment and recycling systems and recycle their waste water economically.

Is it worth it? Not worth it?

It is a legitimate question to ask: how much is it currently worth using biologically treated wastewater in Hungary? If we take into account the lessons learned from the drought year 2022, when in some areas water consumption had to be limited and the fact that summer droughts may persist in the future,

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this issue will not be on the agenda, because the reuse of municipal waste water will be inevitable. Even on a purely commercial basis, there is a justification for this new way of using water. Even if it is not immediately a scarce resource, its price will certainly rise in line with energy prices and the costs of licensing, environmental impact, and investment in line infrastructure. As time goes on and water treatment technologies evolve rapidly, it is becoming easier and more economical to solve more complex water treatment problems. Experience shows that the treatment and technological use of treated wastewater is already much cheaper for companies compared to the price of municipal piped water. Compared with the costs of well water and surface water abstraction and treatment, the difference is not very large. At the same time, the authority is expected to gradually restrict the abstraction of water from nature, particularly in view of the increasing use of water by industry. So it is better to be prepared in time, to design water treatment subsystems to be able to receive and process several different raw water qualities (drinking water/ground water, surface water, treated wastewater, rainwater) simultaneously, and to recycle as much as possible of the industrial waste water generated.

Conclusion

Whichever way you look at it - out of necessity, economically or ecologically - the reuse of biologically treated municipal wastewater for industrial, agricultural and ecological water reuse is already inevitable. Without this, we will hardly be able to meet the water challenges ahead of us, so that Hungary can continue to be a liveable, water-rich, green country in the future. The technologies are ready for the job, and in most cases, economics and environmental considerations are not an obstacle.

Acknowledgement

The outcome of the project "Development of a modular wastewater treatment plant based on MBR technology for the treatment of wastewater from the meat industry (2019-1.1.1-PIACI-KFI-2019-00310)", funded by the National Research, Development and Innovation Office, is a containerizable, highly reliable and highly degradable LPMBR technology and a wastewater treatment plant based on it.

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