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Valorization of Hemodialysis Wastewater: An Emerging Reality

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ABSTRACT

The reutilization and valorization of wastewater contributes to water saving and improve the energetic efficiency of hemodialysis facilities. Moreover, it has the added benefit of reducing environmental impact and providing economically interesting added value products. This review discusses the most recent approaches for the valorization of this type of wastewater.

Keywords: Conservation of Natural Resources; Hemodialysis Solutions; Renal Dialysis; Sustainable Growth; Waste Disposal, Fluid; Water Purification; Water Supply

INTRODUCTION

Water is becoming scare throughout the world and in fact too valuable to waste. In a world where the demand for water continues to grow and the resource is finite, the wastewater, discarded into the environment every day, once treated, can help meet the needs for freshwater as well as for raw materials for energy and agriculture.[1] Wastewater is becoming more widely recognized as an important resource for its water, nutrient, and energy value.[2] The Agenda 2030 for Sustainable Development of the United Nations, Sustainable Development Goal 6 (SDG 6: Clean Water and Sanitation) specifies that countries should halve the proportion of untreated wastewater and substantially increase recycling and safe reuse by 2030.[3] Hence, in the context of a circular economy, whereby economic development must be balanced with natural resources preservation and environmental sustainability, wastewater can be considered an abundant source of precious and sustainable resources.[4] Nowadays, the paradigm of wastewater management is shifting from "treatment and disposal" to "reuse, recycle, and resource recovery". The main benefits of this new concept concern not only human and environmental health, food, and energy security, but also climate change mitigation.[4]

Hemodialysis uses large volumes of water. In a typical session, assuming a dialysate flow rate of 500 mL/min, approximately 200 L of water is used.[5] Wastage water in hemodialysis consisted of wastage from the RO system or reject water and wastage from machines after treatment or spent dialysis effluent. To achieve a transition towards more sustainable hemodialysis, new concepts of wastewater treatment are needed.[6] In hemodialysis, wastewater should be seen as a resource or as a raw material for value addition, that can provide fit-for-purpose water,[7,8] energy,[9] nutrients,[5] and carbon emission savings.[6]

WATER REUSE

The discharge of wastewater in hemodialysis is huge and could be estimated globally at approximately 98 million cubic meters per year, and 18 million cubic meters per year in the United States.[5,10] In our country, Morocco the discharge is estimated at approximately 1 million cubic meters each year.[5,10] The discharged water is a significant resource for which the reuse is less costly than producing desalinated water and represents a good way to conserve fresh water in hospitals.[8]

Reject water from RO system could be reused for floor cleaning, toilet flushing, steam sterilization, irrigation or for industry.[7] This type of wastewater could also be used to replenish sensitive ecosystems by small-scale fisheries and aquaculture.[11]

In the other hand, spent dialysis effluent could be reused for irrigation or landscaping after appropriate treatment for chemical decontamination or pathogen reduction using membrane techniques such as reverse osmosis or nanofiltration.[7,8] A previous business case had demonstrated that treating this type of wastewater could be cheaper and the energy demand could lower than for seawater desalination with a benefit of 20% to 30%.[8]

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NUTRIENTS AND FERTILIZERS RECOVERY

Spent dialysis effluent contains large concentrations of nutrients, which can be recovered as secondary raw materials.[5] As an example, nutrients, such as phosphorus and nitrogen, if recovered from the wastewater flow, can serve as input materials for agricultural fertilizer production,[12] while otherwise, they risk causing eutrophication of water bodies.

The main challenge of recognizing wastewater as a 'renewable' resource will begin with the recovery of these elements. Spent dialysis effluent is a good source of struvite. Although struvite ($MgNH_4PO_4{\cdot}6H_2O$) contains a significant amount of nitrogen and magnesium, it is a phosphate fertilizer and an effective alternative source of rock phosphate for agricultural purposes.[12] In a recent study, we were able to demonstrate that a hemodialysis facility with 20 chairs and 2 shifts/day could generate approximately 2.4 kg of struvite per working day with a profit, and a possibility to fertilize 5.2 ha of arable land.[5]

With regards to struvite recovery from wastewater, relevant information on microbial contamination, antibiotics and antibiotic resistance genes are limited. Previous researches revealed that microbial co-precipitation may recur as little traces.[13] Heating struvite to temperatures just above 35°C or a temperature at which it is expected that crystalline structure of struvite is not yet changing, showed to be an effective way to reduce the numbers of viable pathogens.[13]

Antibiotics and antibiotic resistance genes could also be respectively detected in the struvite recovery. Alternative pathways to control antibiotic contents in struvite might be considered based on their interactions with struvite. One possible method is to adjust the crystallization parameters. Struvite formation and antibiotic residues are dependent on various conditions such as supersaturation, pH, and ionic strength.[14] For example, the response of antibiotics to solution pH is decreased by 3-fold when pH increased from 8.0 to 9.5.[15]

HEAT RECOVERY

The EU Directive 2018/2001[16] specified wastewater as a renewable heat source in compliance with the European environmental goals. Moreover, under the European Green Deal Investment Plan, member states will be provided supportive aid to implement measures like the reuse of waste heat.[17] Hemodialysis wastewater maintains considerable thermal energy quantities, which is discharged to the sewer system with temperature ranging from 20° to 25°C. It is estimated that 1698 GWh per year of thermal energy is lost in sewers in dialysis units all over the world and 314 GWh in the US (The specific thermal capacity of wastewater is : 1.16 kWh/m3 × K; the wastewater in the effluent will be cooled down to 5°C, so that 15 K can be extracted).[5,18]

Globally, hemodialysis wastewater is estimated to contain enough energy to heat 141 500 homes (The average home requires around 12000 KWh of heat/ year),[5,19] with an annual fuel cost savings of 118 million euros if recovered to satisfy heating demands.[7,19] This resource can be exploited through heat exchangers and heat pump technologies, applied at different points in the sewer system. Heat exchangers can be installed in direct contact with the wastewater that serves as a heat source or sink, and is later connected to a heat pump and then to the heating system of a building situated in close proximity.

ENERGY PRODUCTION

Renewable energy can be generated from external sources or recovered from the energy embedded in wastewater. One of the options to consider might be hydropower, where electricity can be generated from the mechanical energy provided by the flow of the sewage from RO system.[20] Hydropower is a well-known technology for renewable energy generation for electricity supply and more recently has started to be studied at a small-scale as a possible solution for energy recovery from hemodialysis wastewater.[9] In a previous study, we have equipped our double-stage RO system with an hydroturbine in order to recover electrical energy from the flow of reject water leaving the RO system. In this way, some of the energy embedded in the wastewater, that otherwise would be wasted, could be harnessed.[9]

CARBON FOOTPRINT REDUCTION

Wastewater treatment can contribute to fighting climate change and reduced CO2 emission. In hemodialysis, the carbon footprint of wastewater is high and estimated to be 0.28 kg of CO2 per each cubic meter of generated wastewater.[7] Accordingly, the global carbon footprint of this type of wastewater is estimated to be 27 400 tons of CO2 per year.

Wastewater treatment can contribute to fighting climate change and reduced CO2 emission. According to International Water Association (IWA), treating wastewater cuts its carbon emission to about one-third.[21] Moreover, the use of wastewater in lieu of synthetic fertilizers can results in an important carbon emissions saving. De Vries *et al*,[22] has estimated that the use of struvite as fertilizer can results in saving of -0.35 kg CO2 eq. kg-1 of struvite.

RESEARCH NEEDS

Hemodialysis wastewater valorization is an emerging concept. To unlock its potential, research is required to identify and explore the technical and economic bottlenecks. Different technically feasible wastewater product portfolios should be analyzed regarding the quality of recovered components and the potential barriers to market success.[6] This is well aligned with achieving the sustainable development goals of the United Nations.

CONCLUSION

Wastewater valorization as a process endeavors to reduce, reuse and recycle the waste into usable, value added and environmental benign raw material. Waste valorization imbibes the natural recycling principles of zero waste.[5] Options for hemodialysis wastewater valorization are diverse and include product obtainment and water reclamation. Many of them are technically, economically, and environmentally feasible but their implementation at industrial scale is limited by the applicable legislation and public engagement.

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