RESOURCE RECOVERY FROM WASTE WATER

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Abstract - Increase in population leads to increase in demands. Driven by environmental, economic and ecological benefits, resource recovery from water draws worldwide attention. Biotechnological processes offer an economic and versatile way to concentrate and transform resources from wastewater into valuable products, which is a prerequisite for the technological development of a cradle-to-cradle bio-based economy. There are many emerging technologies that enable resource recovery from waste water treatment cycle. Bioenergy can be recovered in the form of biohydrogen and biogas, whereas the bio-diesel has gained the attention which could serve as 3rd generation biofuels. Chemical oxidation-reduction and bioelectrochemical systems can recover inorganic or synthesize organic products beyond the natural microbial metabolism. Anticipating the next generation of wastewater treatment plants driven by biological recovery technologies, this review is based on the generation and re-synthesis of energetic resources and key resources.

Keywords - Bioenergy, Cradle to Cradle bio based economy, Microbial metabolism, Resource recovery, 3rd generation Biofuels.

I. Introduction

Waste water and treatment has been in use for a long time and has been evolved in stages throughout the human history. The recent technology has led to treatment of waste water where the resources recovered can be used as a raw material. This concept serves as a substitution for the 3R's (Recycle, Reuse and Recover) concept. This is better known as a cradle to cradle concept.

With wastewater being increasingly recognized as a valued source of renewable resources, the EPA is urging wastewater treatment facilities, which treat human and animal waste, to be viewed as Renewable Resource Recovery Facilities that produce clean water, recover energy and generate nutrients

The potential to transform these facilities exists because wastewater contains potentially marketable products. However, technical, social, and economic challenges remain before treatment plants can realize the full potential of nutrient recovery from wastewater

Numerous individual products can be recovered from wastewater treatment plants, including biodegradable plastics, adhesives, and enzymes useful in biomedical applications. Additionally, several carbon based materials such as biopolymers, PHAs and others, are present in domestic wastewater and perhaps bio solids.

II. Resource Recovery for a Circular Economy

There are a broad range of recovery strategies available, with further differentiation based on product. These feed into almost all categories of agri-industry and chemical production, including potentially, energy economy (including vehicle fuels), raw commodity chemicals, manufacturing and composite industrial inputs, fertilizers, animal feeds, and even consumer products.

The technologies available in India for treatment of municipal water supplies, for industry or for large communities are Clarification, Filtration, Ultra-filtration, Flocculation, Reverse-osmosis, Electro dialysis, Water-softening, Fluoride Removal, Disinfection and Iron removal.

However it is necessary to know how the process works and to find the path of the energy recovered. So a schematic representation of common resource and energy recovery lines in a wastewater treatment plant is shown in Figure 1.

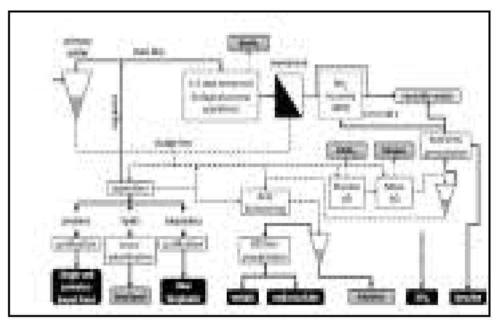

Figure.1.overview of different biological technologies

Energetic products are shown as dashed vertical patterned blocks, whereas raw materials are depicted as black blocks. Wide continuous lines are water lines, dash lines are sludge lines, dash-dot-dot lines are gas lines and double lines represents resources production/extraction.

A. Biofuels

The conversion of organic-rich wastewater streams into Bioenergy has a long history, especially through anaerobic digestion. Several technologies are under current development to convert organic matter to Bioenergy such as biohydrogen, biodiesel, Bioethanol and microbial cell fuels; however, their present feasibilities are far from the reached by anaerobic systems.

B. Biogas

Anaerobic digestion (AD) is a commercial technology applied to convert municipal and industrial organic wastewater streams into renewable energy in the form of methane-rich biogas. Despite energy recovery, AD present other important advantages such as high organic matter removal efficiency, low excess sludge production and low space requirements. Today, AD infrastructure is used to treat a wide variety of organic wastes including (i) sewage sludge, (ii) animal manures, (iii) food and paper industry wastes, including slaughterhouse waste, (iv) energy crops and harvesting residues, including microalgae, and (v) organic fraction of municipal solid waste.

The successful and quick development of anaerobic membrane bioreactors (AnMBR) will further expand the application of anaerobic digestion to a range of new substrates. AnMBR (i) produce high quality effluents (free of solids and pathogens) and (ii) retain special microbial communities able to degrade specific pollutants and/or tolerate higher concentration of an inhibitor regardless of its aggregation or sedimentation properties.

C. Biohydrogen

The dominant technologies for H2 production use fossil fuels consume a lot of energy and have a high carbon footprint. It is necessary that recovered resources satisfy all the necessary conditions so sustainable hydrogen production needs to rely on environmentally friendly and cost-effective technologies. Biological processes, both autotrophic (e.g. biophotolysis) and heterotrophic (e.g. photo-fermentation and dark fermentation), are among the more environmentally benign methods for H2 production.

D. Biodiesel

Although H2 and methane (after biogas upgrading) can also be used as vehicle fuels, biodiesel represents a smoother alternative since it can be used in existing engines as well as distribution and supply infrastructure without major modifications. Feedstock cost is one of the main challenges to make microbial biodiesel profitable. Heterotrophic microalgae have also been successfully cultivated using several waste and wastewater streams.

E. Recovery of Metals

Contamination of water sources by metals is of big concern. The origin of contamination is mostly related with anthropogenic activities. Some of the metals are finally disposed into domestic wastewater treatment plants (DWWTP), the sources including partially treated industrial effluents; disperse contamination points, runoff from roads as well as soil leachates from highly contaminated ponds and soils as uncontrolled landfill lsand mines. The metals are usually removed from DWWTP and accumulated in domestic sewage sludge, where more concentrated metals (>10 ppm) have been identified as Fe,Al, Ti, Zn, Cu, Sn, Mn, Cr, Mo, Ag, Ni, U and V, although this composition can substantially vary depends on the geomorphology and human activities.

III. Microbial Fuel Cells

Microbial fuel cells (MFC) are an alternative for AD, which directly delivers electricity. This is a system which generates bioelectricity from biomass using bacteria. Through oxidation of organic matter by microorganisms, electrons are produced which are used to create power. Common MFC systems consist of an anode and a cathode chamber separated by a membrane. The bacteria grow in the anode chamber while electrons react with the catholyte in the cathode chamber. In the system, used water is treated at the same time as energy is produced through conversion of chemical energy into electrical energy. Ammonia can further be recovered through this process.

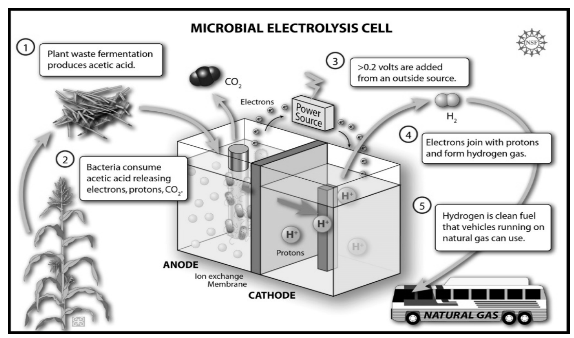

Figure 2.Microbial Fuel Cell

IV. Components

Many components can be recovered during the treatment process of used water and from residuals from water treatment, such as nutrients, metals and biodegradable plastic. Some examples of recovered components are provided below. The two most prominent nutrients that are discussed in terms of resource recovery are phosphorus and nitrogen. These are both critical components to the agricultural system worldwide.

A. Phosphorus

There are two main possibilities of recovering phosphorus from municipal used water, namely recovery from used water treatment and recovery from produced sludge. Recovery from sewage sludge results in, for example, magnesium ammonium phosphate (MAP), calcium phosphate and iron phosphate. MAP is more commonly referred to as struvite and can easily be separated from used water due to its specific gravity.

A method in which phosphorus can be recovered from sludge is through supercritical water oxidation (SCWO), a technique which is growing in terms of practice and commercialization. The process destructs organics in the sewage sludge and leaves slurry of inorganic ash in a water phase free from organic contaminants. Components, such as phosphorus and coagulants, can then easily be recovered. There are certain factors that need to be considered when recovering metals. Such features include initial concentrations of all metals, origin of used water, identification of metals to be recovered and the choice between recovering one specific metal opposed to a group of metals. Furthermore, different removal technologies have different benefits. Some have short processing time while others have cheap and easy monitoring systems.

Several techniques have a complete removal of metals from water while others have partial removal of some particular metals from the residual ash. As such, phosphorus removal therefore depends on the production of biomass and precipitated Sludge. The majority of the processes involved in recovering a phosphorus product need chemical consumption. Crystallization has been proven to be the established technology with the highest percentage of recovered resource for phosphorus, with a recovery rate exceeding 90%.

B. Nitrogen

While many multiple technologies remove nitrogen, not as many can recover the resource. Nitrogen removal can be done either biologically or physico-chemically. The selection of the method is based on the concentration of nitrogen in used water. In order to efficiently recover nitrogen from used water, techniques typically require concentrations above 1,000 mg NH4/L.

Nitrogenous materials present in the sewage or paper mill effluents can be removed from sewage effluent and converted into biomass through activated secondary treatment processes. A technology of protein-based wood adhesives sourced from secondary sludge is further currently being investigated.

Fertilizer grade ammonium sulphate can be produced from the high ammonia-nitrogen concentration side streams from Sludge digestion processes by stripping and adsorption. This stream can also be treated biologically by nitration and anammox, the latter being autotrophic denitrification. While not resulting in nutrient recovery, this approach significantly reduces energy requirements compared to the conventional nitrification/denitrification process and eliminates the carbon requirement for heterotrophic denitrification.

Stripped ammonia can be recovered via condensation, absorption or oxidation, resulting in a concentrated fertilizer product. Nitrate/nitrite species can further be recovered through using liquid-liquid extraction technologies. This method is based upon the technique of separating components based on relative solubility in two immiscible liquids. The end result is a concentrated nutrient solution which can be stripped from the organic phase.

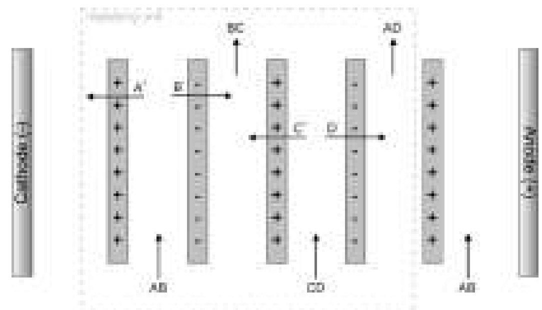

Figure 3. Electro dialysis

BP: bio polar membrane; A: anion-selective membrane, C: cation-selective membrane

Another way in which ammonium can be removed from the stream of used water is through electro dialysis. The approach is to first concentrate nutrients into appropriate dialytic leaves in an overall electro dialysis cell and subsequently recover through a range of technologies, including precipitation, adsorption, desorption and air stripping. The technology is founded on the method of using an electrical current in which anions and cations are separated across ion exchange membranes. Multiple nutrients can be recovered through this process but it is most suitable for nitrogen and potassium. As with phosphorus, WERF states that among the established techniques, crystallization is a technique with a high percentage of recovery efficiency. The process of obtaining struvite is such an example, in which nitrogen is recovered in addition to phosphorus.

V. Conclusions

This review has focused on technologies which enable resource recovery. The drivers are clear, and are to translate technologies which would normally remove contaminants into a liquid or waste concentrate stream (or reactively dissipate them) into products that feed into the circular economy. This is not a massive shift from current practices, but instead of focusing the process on removal, it focuses on recovery. Water and wastewater treatment infrastructure is facing a significant, and growing, funding gap in the India. The prospect of reducing the cost of treatment, or increasing the revenue generated through the production of additional marketable energy, nutrients and commodities is an appealing one.

The idea of recovering valuable products from wastewater may once have seemed fanciful, but it's a prize that many in the water quality community are working towards. It not only helps to reduce the disposal of waste water but also increases the economy of the country and also the desire to bring a major change in the community.

Of the wide variety of innovative projects underway not all will succeed, but those that do may just hold the key to plugging the funding gap for India’s wastewater treatment plants

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