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Research paper

Review of Techniques Currently Used for Treatment of Domestic Waste Water

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Abstract

Nowadays, the main problem faced by WWT (Waste Water Treatment) plants all over the world is the large amount of energy consumed and the ineffectiveness in treating Contaminants of Emerging Concern (CECs) the presence of which is constantly increasing in the municipal waste water. The conventional treatment method also requires large amounts of lands making the entire treatment process very costly. Alternate methods like use of ozone is showing promising results. The objective of this paper is to review the various techniques for the treatment of municipal waste water mainly for the removal of heavy metals and CECs and the energy consumed.

Keywords: *CECs, energy, heavy metals; waste water*

1. Introduction

Water is a resource found all over the earth. It is required by humans, animals and plants to survive. 70% of the earth's surface is covered with water but less than 2% is fresh and usable. Water consumption by humans can be categorized under industrial, domestic and agricultural purposes. (P.Rajasulochana, 2016). Water which has been used for any purpose forms waste water which is disposed either in water bodies close to the place where it is generated or on land. Various constituents of waste water can be listed as pathogen and non-pathogenic organisms, organic and inorganic particles, soluble organic and inorganic material, animals, gases, emulsions, various macro solids and toxins.
An increase in population and subsequent increase in the quantity of waste produced led to failure of this mechanism as it resulted in pollution of water bodies. Absence of water bodies led to disposal on land which resulted in similar pollution of land and ground water table due to leeching. Industrialization and urbanization led to increase in volumes of waste water generated.
Treatment of this waste water was then introduced in order to reduce the effects of pollution. It is increasingly used for irrigation in urban and peri-urban areas (P.Rajasulochana, 2016). Waste water treatment (WWT) consists of various steps namely separation, removal and disposal of various pollutants present in waste water making it safe to reuse or dispose at a later stage. The basic methods involved are physical, chemical, mechanical or biological. Most of the waste water are treated in industrial scale plants referred to as WWTPs. However, use of septic tanks and other On Site Sewage Facilities (OSSF) is also widespread in rural areas and areas not connected to central sewerage facilities. This proportion is approximately 25% in the US (Rojas J, 2012). The sludge generated after the treatment may be used as landfill or may be disposed in water i.e. by dilution.
Most of the conventional methods that are used for WWT are in use since ancient times and are not economical. Newer, advanced and greener techniques are hence being introduced in order to overcome these drawbacks. (Turoskovy, 2000)

2. Historical background

WWT gained importance as it could reduce the pollution arising due to disposal of waste water in the environment – whether on land or in water. The increase in population led to further reduction in the availability of land for the treatment plants. Also, greater population led to greater quantity of polluted water entering the water bodies. Due to this, self-purification of the water bodies became impossible.
The need for alternate methods was felt in order to speed up the natural decomposition methods and requiring lesser land area. The objective of treatments could be listed as follows:
1) Removal of floating/suspended particles
2) Removal of BOD
3) Removal of Pathogens
Since 1990, increased scientific knowledge and understanding of long term effects on environment due to waste water has led to an awareness of health issues resulting from the release of various toxic and potentially toxic chemicals in the environment. (I. Bakkaloglu, 1998)
WWT plants began to lay more importance on aesthetics and environmental concerns and due to this removal of nitrogen and phosphorus which was the main cause of eutrophication and algal bloom. Many more treatment objectives were added and stringent laws put in place in order to control the quality of discharged effluent.
A typical WWT system has a primary and secondary treatment method which is then followed by the disposal of solids and water thus generated. The presence of suspended / floating matter de-

cides the necessity of a preliminary treatment. A septic tank is an example of simple primary treatment which carries out anaerobic treatment to remove settleable solids. Areas having poor soil conditions and high water table can be served by them. The most important concern with a septic tank is that the effluent may still contain pathogen and hence be unsafe. Other options of secondary treatment like sand filters may be used to reduce the pathogens but may not work efficiently in all areas.

Recent years has seen the presence of a new group of contaminants in the waste water known as emerging contaminants-ECs. Pharmaceutical residuals, personal care products (PCPs) and endocrine disrupting chemicals (EDCs), surfactants, various industrial additives and numerous chemicals are classified as emerging micro pollutants. These have been recognized as a water pollutant having adverse effect on human and animal endocrine system. Natural attenuation and conventional treatment process cannot remove these pollutants which are found as traces – concentrations varying from µg/L to ng/L but these bio-accumulate in the various organisms in food web starting from macro invertebrates to humans. (N.Bolong, April 2009)

The presence of these contaminants is a matter of concern for the health and safety of the consumers. The conventional WWT plants are unable to remove them as they were not designed for their removal. Monitoring of these contaminants is not possible as there are no laws in place specific to these ECs. Discharge of these com-pounds into the aquatic system affects all the living organisms in it. (N.Bolong, April 2009). Organic micro pollutants such as pharmaceuticals are also known as persistent pollutants as they are degraded only partially in the WWT plant. (Sonia Arriaga, December 2016)

3. Removal of metals and heavy metals

Earlier, metals were removed by filtration, activated charcoal, flocculation etc. (T. Karthikeyan, 2005), (K. Vijayaraghavan, 2007) .These methods are no longer adequate due to the stringent regulatory limits for the effluent water. In order to remove heavy metals methods like ion exchange, carbon adsorption, chemical precipitation, evaporation and membrane processes are used. (J. Wang, 2009). Activated carbon and rice husk were successfully applied for the removal of Fe (III) and Mn (II) ions in Egypt (Mamdouh S.Masoud)

Selection of method is decided by the type of waste, concentration and heterogeneity of the influent as well as the desired standards of effluent. Availability and low cost of raw material along with better performance have led to increasing use of biological methods for the recovery of toxic/ precious metals from domestic and industrial waste waters such as algae, fungi and yeast. (N. Mallick, 2003),(S.S. Ahluwalia, 2007), (H. Benaissa, 2007), (S. Bunluesin, 2007), (Ansari M.I., 2007).

Biological systems are used for the treatment of radio nuclides and heavy metals from the effluents. (Massoud M.A., 2009) (J. Parkinson, 2003). These biological treatment processes make the use of the ability of various micro-organisms to digest the constituents of waste water and also provide metabolic energy. The contaminants get eliminated due to this metabolic activity. (I. Bakkaloglu, 1998). The various methods used for final treatment are adsorption, post – precipitation, ion exchange, reverse osmosis and electro-chemical treatment. (N. Matsumotto, 2007)

4. WWT and energy consumed

Earlier WWT plants were designed mainly for treating the effluents and bringing them to desired standards without giving much thought to the energy requirements. Present day scenario where economic crisis, volatile oil and energy prices, increase in the greenhouse emissions coupled with the near foreseeable depletion of non- renewable energy resources make it necessary to use more sustainable energy forms and measures to ensure sustainable economy in the future. (Rojas J, 2012)

WWT plants are very expensive to operate as they are highly energy intensive. Most energy is consumed by pumping stations (22%) and activated sludge aeration (42%) **(**Park S., 2007**)**. In the US, for example, WWT plants alone consumed 2% of the total energy generated [20] and their energy consumption is expected to increase by 30–40% in the next 20–30 years (Metcalf, 2003**)**. In fact, WWTPs represent the single largest cost to local governments with up to 33% of their total budget. New York's wastewater sector uses approximately 25% more electricity on a per unit basis than the national average (1480 kWh/MG kilowatt hour per million gallons as against an average of 1,200 kWh/MG (Yonkin, 2008). As energy and water are critical elements, the scenario is now changing with more focus on saving both of them (Scott C.A., 2011) (Panepinto D, 2016). The urban water system is dependent on energy for both conveyance and treatment of water due to the growing scarcity of water (Lazarova V, 2012). Also, the growing climate concerns, energy efficiency, energy saving and energy substitution have become a common development principle all over the world. (I Dincer, 2002) (Friedrich E, 2009) It is essential to reduce the net energy consumption in WWT plants. Reduction in energy consumption for WWT is a complementary and not alternative goal to water reuse. (McCarty P.L., 2011)

In any conventional WWT plant, approximately 25-40% of the operating cost can be attributed to its energy consumption. It usually consists primary, secondary and advanced stages of treatment. The energy intensity of raw wastewater collection and pumping ranges from 0.02-0.1 kWh/m^3 in Canada, 0.045-0.14 kWh/m^3 in Hungary and 0.1-0.37 kWh/m^3 in Australia. It was reported that the average energy input of conventional activated sludge (CAS) treatment systems is 0.46 kWh/m^3 (Australia), 0.269 kWh/m^3 (China), 0.33–0.60 kWh/m^3 (USA) and 0.30–1.89 kWh/m^3 (Japan). The aeration process in secondary treatment is the highest energy consumption part of the wastewater treatment technology. In most medium and large WWTPs with CAS systems, aeration takes up approximately 50-60% of all electricity consumption, while, sludge treatment consumes 15–25% of energy, followed by secondary sedimentation including recirculation pumps (15%). The results of general energy distribution in CAS systems are presented in Figure 1. Compared with CAS system, oxidation ditch has higher energy demand of 0.5–1.0 kWh/m^3 (Australia), 0.302 kWh/m^3 (China) or 0.43–2.07 kWh/m^3 (Japan) due to the longer hydraulic retention time and greater power consumption for higher specific oxygen demand (Panepinto D., 2016)

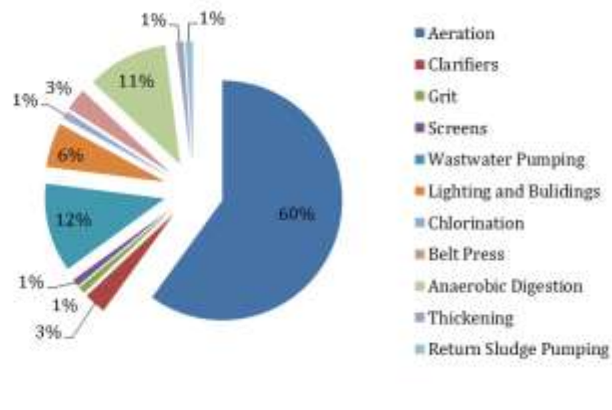

Figure 1: Energy requirement distribution in conventional activated sludge systems (Panepinto D., 2016)

Industries consume approximately 50% of the world energy. One of the targets of energy policies in Europe is to reduce energy consumption by 20% by 2020. In order to achieve this, energy consumption in industries has to be reduced greatly. (João Henriques, 2016) Eco- efficiency aims at improving the economic and ecological efficiency of various companies by attaining higher outputs with fewer inputs, materials and energy, more outputs but fewer wastes. (João Henriques, 2015). Energy audit results show an average savings of 20-40% with some values as high as 75%. 53% of energy consumption takes place in aeration and over 12% in pumping operations. The efficiency of removal of pollution load is directly related to the energy consumption. (João Henriques, 2017)

Turning waste into energy is a part of circular economy which allows the value of materials, resources and products to be maintained in the market for a long time, thus reducing waste and usage of resources. All member states of EU are looking out for a more intelligent waste treatment method which will include circular approach in their waste policies. (J. Malinauskaite, 2017). Due to strong growth in energy intensive wastewater treatment, public agencies and industry have now began to explore and implement measures to ensure achievement of the targets indicated in the 2020 Climate and Energy Package. However, in the absence of fundamental and globally recognized approach evaluating wastewater treatment plant (WWTP) energy performance, these policies may turn out to be economically wasteful. (Stefano Longo, 2016)

5. Removal of CECs

Antibiotics are a source of contaminant of emerging concern (CECs) which are often found in water sources. Antibiotics exert selective pressure on microbial communities such that even trace concentrations result in development of resistance to antibiotics, affect cell signalling processes, and alter carbon and nutrient cycling in ecosystems. Hence, advanced treatment processes to remove them from the water are required. Ozone is a highly reactive oxidant having selectivity for those moieties generally found in antibiotic molecules. Ozone and ozone-based advanced oxidation processes, which promote ozone decomposition to hydroxyl radicals, are quite effective at transforming antibiotics in real systems. Hence, ozone-based processes offer an effective solution to this emerging threat. (Blaney, 2014)

A study compared the removal of PPCPs and other micro pollutants, energy consumption and waste production from treated waste water by ozone/bio filtration and reverse osmosis (RO). 4-8 mg/L doses of ozone were found to be as effective as RO. Considering the overall environmental impact like consumption of energy, water recovery and waste production, ozonation is a more desirable process for the removal of micro pollutants. **(**Carson O Lee, 2012)

Various catalysts may be used to improve the decomposition of ozone to form hydroxyl radicals. Fe-based materials are the new promising catalysts for catalytic ozonation for the removal organic pollutants (Jianlong Wang, 2017)

CECs have responded well to ozone treatment. The performance of ozone when the technology is used for disinfection to overcome multiple risk factors such as disinfection, CEC removal, endocrine activity and toxicity for real effluents collected from three WWTPs. Two secondary effluents required mean specific ozone doses for disinfection of 0.25 and 1.04 gO_3/gDOC (dissolved organic carbon) whereas the advanced primary effluent required 1.52 gO_3/gDOC to achieve a total coliform target disinfection criteria of 1000 MPN/100 ml (equivalent to 200 MPN/100 ml E. coli). At ozone doses for disinfection, CECs with high reactivity with ozone were removed at levels greater than the target CEC removal of 80% for all WWTP effluents. For the secondary effluents, ozone doses above 2.6 ± 0.6 gO_3/gDOC were required to satisfy the target removal for the recalcitrant CECs. Within the disinfection ozone dose range, estrogenic activity was reduced by more than 98% and androgenic activity was removed by more than 68%, while the anti-estrogenic activity remained unchanged (Deniz Nasuhoglu, 2018) The removal reached 95% across all the tested treated antibiotics with ozone dose as low as 75 mg/ lit (Omar A.Alsager, 2018)

Another test by Wang H in 2018, deals with ozone based processes for reuse of water taking into consideration municipal waste water reclamation and also drinking water treatment. The main limitation in ozonation is the low mineralization achieved which leads to the formation of toxic reaction intermediates. Light aided systems and hydrogen peroxide when used enhance the effectiveness of ozone action over the pollutants. Special interest is now given to solar light catalytic ozonation systems for control of biological and chemical contaminants. Another cost effective method for water treatment is the integration of ozonation and sand bio filtration which needs further studies in order to understand the mechanism of bio filtration. (João Gomes, 2017)

Conventional treatment reduces the pathogen concentration by 90 -99.99% except for adenovirus and parvovirus where efficiency was lesser. Ozone treatment further reduces the pathogen concentration by 90-99%. Thus proving that ozonation is a promising technique for decreasing pathogenic human virus transmission. (Wang H, 2018) It is found that the hydraulic loading has almost no effect on the ozonation efficiency. Variation in efficiency of ozonation in case of waste water cannot be linked to pH or nitrite concentration. Hence, it is not possible to use the data from one WWT plant to optimize the operation in some other plant. For a given WWT plant, under varying weather conditions, similar removal rates are seen for same ozone dose (TOC normalised). The compounds that were removed quantitatively under dry weather were still removed well with three times dry weather flow (H.Eltaliawy, 2017)

In another study, ozonation alone and in combination with aerobic biodegradation was used for pharmaceutical waste water treatment having TOC of 803 mgC/L and COD of 2775 mg/L. Ozonation showed up to 99% degradation of amoxicillin content and also colour removal with 1g/L ozone consumption. Though only ozonation did not give complete mineralization of pollutants. In order to improve efficiency of treatment and cost efficiency, combination of ozonation and aerobic biological degradation was suggested. This showed removal of more than 99% of amoxicillin content, more than 98% of COD and original colour. (Rafaela B.P. & Marcelino, 2016)

6. Conclusion

Space and energy constraints and the presence of CECs will soon render the conventional WWT methods obsolete. Newer methods have to be identified which will provide solutions to the above. Ozonation shows promising results with respect to the removal of CECs. More emphasis should be given to the sustainability of the methods adopted. Quicker methods which will satisfy the effluent quality standards are the needs of the hour so that smaller units may satisfy the needs of the treatment of domestic waste water.

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