Mini Review

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Critical review of pollution control technologies

Abstract

Industrial operations generate various wastes such as effluent, emissions and solid wastes that pose environmental and health problems. The effluent released from the industries finds its way into natural water resources and degrade water quality. On the other hand, the emissions are bound to affect ambient air. The solid wastes create public nuisance by way of foul smell if it is not handled properly. Effective management of the wastes include waste minimization, segregation of wastes, processing of wastes to make possible recoveries of resources, treatment and final disposal. The paper gives a critical review of pollution control technologies currently in use for treatment of effluent and avenues for recovery water and other materials from the effluents.

Keywords: industry, effluent treatment, pollution control, treatment technology, membrane filtration

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Introduction

The effluent generated from the industries is mostly treated using primary, secondary, tertiary and the advance treatment methods. The first step in the water pollution control is to minimize the pollution load in effluent that can be effected by preventing the raw materials or products from entering into the effluent streams. Segregation of highly polluting effluent stream from the low polluting stream followed by treatment of each effluent stream separately, gives better performance of the effluent treatment system.[1] In some cases, effluent of one industry can become the raw material of the other industries. For instance, the molasses (highly polluting effluent stream) generated from the sugar mill is used as a raw material in the fermentation (distillery) industry for production of alcohol. The second step in the effluent treatment is to collect and equalize the effluent streams that are discharged at different intervals from different stages of product manufacturing. The equalization ensures uniform characteristics in terms of pollution load, pH and the temperature. Screening and oil trap, prior to the equalization, is provided for removal of the floating solids or oil. The effluent is further treated in the primary treatment unit including addition of the coagulants such as lime, alum and polyelectrolyte followed by clariflocculator or flocculator and settling tank. Selection of the appropriate coagulants and doses of the coagulants are determined on the basis of the treatability study of effluent samples. The primary treatment helps in reduction of the total suspended solids (TSS). A significant reduction in biochemical oxygen demand (BOD) and chemical oxygen demand (COD) concentrations is also achieved. The primary treatment is followed by the secondary treatment i.e. aerobic biological treatment process and the settling, which further reduces BOD and COD concentrations in the effluent. The effluent with high BOD and COD concentrations, as in the case of slaughter houses and distilleries etc., two stage biological treatment system is preferred. Installation of an anaerobic (biomethanation) reactor prior to the aerobic treatment can facilitate recovery of methane gas and manure. The methane gas can be used as fuel in the boilers, fluid heaters and DG sets. The advance treatment technologies involving evaporation and incineration are also practiced. The advance oxidation and electrochemical coagulation process of effluent treatment have been explored for the treatment of industries.

The treated effluents confirming to the prescribed standard can be discharged into inland surface water. Barring the effluents generated from tanneries, pulp and paper, textile industries and chemical industries, the effluent of some other industries can be reused for irrigation after treatment to the standards.[2,3] However, this mode of disposal is site specific and requires extensive monitoring of the soil and ground water quality. In India, Brazil and other countries, irrigation practices using the treated effluents from distilleries and sugar industries are prevalent.[4] Composting of the distillery effluent after mixing it with the agriculture wastes (such as press mud of sugar industries) is also being used. The compost produced contains nutrients (N, P and K) and the same can be used as manure. The effluent treatment process and technologies are given in Table 1. Depending upon the pollution load, one or more than one of the treatment methods are selected for the treatment of effluent.

Table 1 Pollution control processes and technologies for industries

S. No.	Level of treatment	Treatment processes
1	Preliminary treatment	Screening, Oil trap
2	Primary treatment	Equalization, Neutralization, Chemical treatment Electrochemical coagulation
3	Secondary treatment (Biological treatment)	Anaerobic treatment, Aerobic treatment, Composting
4	Tertiary treatment	Adsorption, Ozonation, Chlorination, Advance oxidation, polishing pond
5	Advance treatment	Concentration (Evaporation, membrane filtration, mechanical vapour recompression), Crystallization, Drying, Incineration

Critical review

The chemical treatment techniques provide an onsite solution for the effluent disposal. The process involves addition of Al^{3+} (alum), Ca^{2+} (lime), Fe^{3+} (ferric chloride) or Fe^{2+} (ferrous sulphate) to the effluent stream followed by mixing and flocculation. Sometimes, more than one coagulant is used to enhance the efficiency of the treatment process. The main drawback associated with the chemical processes is that they generate large quantity of sludge containing heavy metals requiring safe disposal. The electrochemical coagulation has recently attracted attention as a potential technique for the treatment of industrial effluent due to its versatility and environmental compatibility Khandegar et al. 2013. The technique uses direct current source between the metal electrodes immersed in effluent, which causes the dissolution of the electrode plates into the effluent. The metal ions, at an appropriate solution pH, forms wide range of coagulated species and metal hydroxides that aggregate particles and adsorb the dissolved contaminants. The process is characterized for a very high efficiency.[5,6] The high cost of electricity and the cost of sacrificial electrodes can result in an increase in the operational cost of electrochemical coagulation. Ozonation is widely used for the treatment of effluents. The requirement of ozone is met with an onsite ozone generation plant using atmospheric oxygen. The process is quick and effective for most of the organic pollutants and generates no solid waste stream after the reaction. Besides reducing the pollution load in the effluent, it removes bacteria, virus, odour forming substances and degrades non-biodegradable molecules.[7] Chlorine is a strong oxidising agent and has been extensively used for the purification of the raw water for drinking purposes. It also finds application in the effluent treatment.[8]

Hydrogen peroxide is widely used in the bleaching operations. The hydrogen peroxide along with an iron catalyst, known as Fenton's reagent, forms a strong oxidizing agent for use in the effluent treatment.[9] It has been reported in the literature that the advanced oxidation methods for the colour removal include combination of the oxidants such as UV-H_2O_2, UV-ozone, H_2O_2-ozone and Fe_2+-H_2O_2.[10] The oxidation processes have the potential for use in the effluent treatment although all these methods are unattractive due to the financial constrains.[11] The biological processes are broadly classified as aerobic and anaerobic, and several variants are available in each of the system. The combination of anaerobic and aerobic processes is also used to enhance the treatment efficiency. The biological treatment of effluent provides a most economical mean for the effluent treatment compared to the physical and chemical methods. The biological process generates little or no secondary hazard in the form of sludge and is environmental friendly.[12] The application of the biological process has limitations such as long retention time, requirement of large land area and low efficiency. Further, the process is sensitive to the temperature and pH of the effluent and the presence of toxic contaminates like heavy metals require efficient pre-treatment. The adsorption process using the activated carbon as the adsorbent is commonly used for the removal of organic pollutants from the effluent.[13] There is no generation of sludge from the adsorption process, which has been the problem with the chemical treatment processes. The adsorption process is insensitive to the toxic contaminants such as heavy metals in the effluent. Further, adsorption process based treatment system is easy to design and requires less area for operation. However, the exhausted activated carbon requires regeneration, which leads to the loss of the carbon and adds to the cost of operation. Despite this, the adsorption process has been the choice of engineers due to effectiveness in effluent treatment.

The membrane filtration includes reverse osmosis (RO), nanofiltration, ultrafiltration and microfiltration.[14] The reverse osmosis and nanofiltration are used for the recovery of the water and other materials from the effluent streams whereas the ultrafiltration is applied as a pre-treatment measure.[15,16] The permeate of the reverse osmosis with almost no colour content and low total dissolved solids (TDS) can be reused and recycled in the process.[17,18] The nanofiltration removes all the impurities and allows the passage of salt with the permeate stream. With the use of nanofiltration, the permeate (brine) can be recovered from the textile dyeing effluent.[19,20] The membrane filtration processes are effective for the removal of all types of pollutants including colour. However, the disposal of the reject stream of the membrane filtration is a problem. Further, the high operating pressure, fouling and replacement of the filter media make the process expensive.

The concentration of effluent is achieved usually with a multiple effect evaporator, which is generally a vertical cell in which stainless steel tubes are mounted. Some evaporator systems work on falling liquid film theory which means that the tubes are not filled up with liquid but a liquid film on inner surface of the tube is established that evaporates leaving behind a more concentrated effluent. The concentrated effluent is dried to convert the concentrate into powder. Alternatively, the concentrated effluent is incinerated to convert the pollutants into ash. The dry powder or ash can be used as nutrient for the agriculture crop or disposed as a solid waste. The drier and incineration technologies have been used for the treatment of the distillery effluent.[4] Besides reducing pollution with the application of the effluent treatment technologies, efforts have been made to take measures that reduce pollution load including the segregation of effluent streams to recover the water and chemicals from the effluent. In case of pulp and paper industries, lignin and chemical recovery systems are installed in a few industries. The textile industries have succeeded in recovering the sodium chloride and glauber salt from their effluents with the application of advance treatment technologies such as membrane filtration and crystallization.[16] The advance treatment technologies such as reverse osmosis, nanofiltratin, dryer and the incineration, while reducing the pollution problems of the industries, facilitate recovery of the water and other materials from the effluents that is a step towards the sustainable development.

Conclusion

The effluent generated from the industries is treated using primary, secondary, tertiary and the advance treatment methods. While the primary treatment system is intended reduce solids and oil contents together with adjustment pH, the secondary treatment reduces organic content in the form of BOD and COD. The tertiary treatment is provided to remove specific pollutants. Advance treatment methods include advance oxidation process, membrane filtration, drying, incineration and crystallization. The primary, secondary and tertiary treatments help reduce pollutants to acceptable limit for disposal of effluents. The advance treatment technologies, while reducing the pollution problems of the industries, facilitate recovery of the water and other materials from the effluents that is a step towards the sustainable development.

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Conflict of interest

The author declares no conflict of interest, financial or otherwise.

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