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[1.] Arshad ALI, [2.] Hashim Nisar HASHMI, [3.] Naseem BAIG

TREATMENT OF THE PAPER MILL EFFLUENT - A REVIEW

[1,3.] NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY, ISLAMABAD (MCE-NUST), PAKISTAN
[2.] UNIVERISITY OF ENGINEERING AND TECHNOLOGY, TAXILA, PAKISTAN

ABSTRACT: The disposal of untreated paper mill effluent is a major environmental concern today. The purpose of this paper is to highlight the available treatment units for the paper mill effluent and to recommend a possible best option for the developing nations, like Pakistan. Various physcio-chemicals, anaerobic, aerobic, combination of different treatment units have been evaluated, on the basis of their treatability performance, especially in terms of COD, BOD and AOX removal efficiency. It is concluded that the physcio-chemical and aerobic processes are uneconomical and impracticable, owing to their high operational cost. Whereas, the anaerobic processes seem to be more reliable, simple and feasible for the developing world, both in terms of pollution reduction and low operational costs.
KEYWORDS: Paper mill, chemical oxygen demand, aerobic, anaerobic

INTRODUCTION

There are thousands of paper mills operating world-wide that produce more than 450 million tons of paper, to meet the daily requirements. And it is expected that the demand of paper usage will reach to 500 million ton per annum by the end of 2020. This rapid industrialization has put adverse impacts on the entire environment. The paper mill is considered to be one of the major units in terms of fresh water usage, and also in terms of producing highly toxic effluent. In Pakistan, more than 400,000 tons of paper is produced annually by sixty different paper mills. That release about 36,000 cubic meters of wastes per day. This effluent of the paper mill is highly polluted, in terms of its higher COD (Chemical Oxygen Demand), BOD (Biochemical Oxygen Demand), AOX (Absorbable Organic Halides) and TSS (Total Suspended Solids) concentrations. The AOX content of the wastes is highly persistent, bio-accumulative and carcinogenic in nature. Dioxin, which is known to be the most toxic substance ever found on earth, also belongs to the family of AOX, and has been reported to be present in the effluent of paper mill Paper Indust (Savant et al. 2005). But unfortunately still, most of this effluent is directly disposed off into the receiving streams without any proper treatment. It is one of the major environmental challenges being faced by Pakistan (Ali et al. 2001).

A lot of work has been done at various levels to address the issue of paper mills effluent by environmental scientists, engineers, legislator and policy makers. Different techniques, namely pyscio-chemical, biological, have been tried to reduce the pollution load of the paper mill effluent. And most of them are highly valuable in terms of their efficiency and reliability. Since, the developing countries are subjected to higher degree of environmental pollution, due to the disposal of untreated domestic and industrial effluent; therefore it is very much essential to work-out cheapest available treatment techniques. The main purpose of this paper is to highlight the available treatment techniques in terms of their applications, and to suggest the most viable option for the treatment of paper mills effluent for Pakistan.

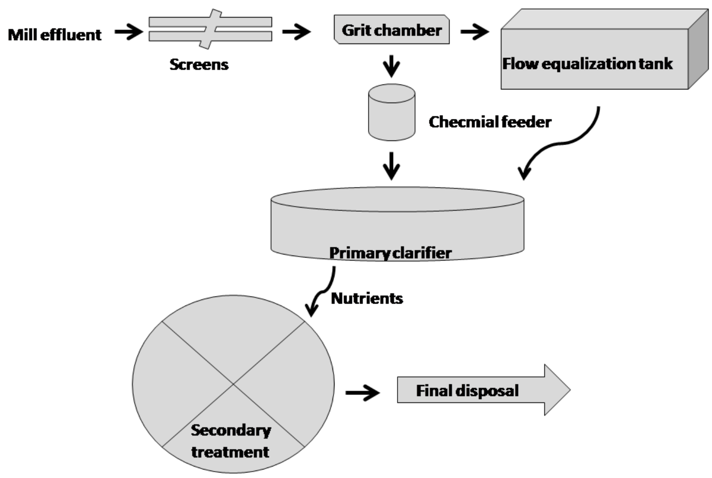

Figure 1. Typical layout of paper mill effluent treatment plant (Thompson et all, 2001)

BACKGROUND

Figure 1 shows a typical layout of the wastewater treatment plant used for the paper mill effluent, as illustrate by different authors. It consists of screening chamber, primary sedimentation *tank and biological treatment unit. Though, the wastewater pollution of the paper mill could also be reduced by adopting some environmental friendly management measures, like replacing the use of chlorinated compounds that are used during the bleaching process of paper making with EFC (Elecmental Free Chlorine) radical. But this type of process modification reduces the concentration of COD/BOD to a certain limits only. Still effective and efficient techniques are required to reduce the excessive pollution load of the paper mill effluent before its final disposal.*

Table 1. Wastewater characteristics of the paper mill effluent (Arshad and Hashim, 2012)

Parameters	Concentration	Parameters	Concentration
pH	8.4	COD (mg/L)	1810
Color (units)	1736	TSS (mg/L)	958
Lignin (mg/L)	452	TDS (mg/L)	1524
AOX (mg/L)	32	BOD (mg/L)	960

The biological treatment unit in case of paper mill effluent treatment normally consists of an activated sludge process or anaerobic digestion or sometimes even the combination of both the processes are used (Thompson et al. 2001). Tertiary treatment units are also used, but very rarely, either to polish quality of the final effluent, or might be to reduce the toxicant concentration in the effluent, in accordance to the available legislations. Table 1 shows the wastewater characteristics of the paper mill effluent in Pakistan.

AVAILABLE TREATMENT TECHNIQUES - PHYSCIO-CHEMICAL TREATMENT UNITS

Saunamaki (1997) found that the sedimentation tank can remove more than 80% of the suspended solids at a SLR (Surface Loading Rate) of 1.4m^3/m^2-hr. But they were observed to be less effective in terms of BOD or COD removal. Since, the suspended particles within the paper mill effluent mainly consists of bark particles, fiber debris, filler and coating material etc, therefore, it was suggested by Haarhoff and Bezuidenhout (1999) to use dissolved air floatation system, as a pre-treatment unit for biological treatment process. And the same combination has been found quite useful when applied to the effluent treatment of Shotton Paper Mill UK and Hallsta Paper Mill Sweden. Its treatability performance was observed about 90% in terms of suspended solids removal (Wenta and Hartmen 2002). In a study performed by using an activated carbon, more than 90% COD removal has been observed (Shawwa et al. 2001).

Simlarly, by using the blast furnace dust and slag 60% lignin has been found to remove from the effluent of paper mill (Das and Jain, 2001). Different coagulants like horseradish peroxide, aluminum sulfate, polyethyleneimine, polyelectrolytes, calcium sulfate, aluminum sulfate, chitosan etc are found effective in terms of reducing the COD, BOD, AOX and turbidity of the paper mill effluent. And in some similar studies, the reduction in the toxicity of bleached paper mill effluent has also been observed to decreased (Rohella et al. 2001, Torrades et al. 2001).

The ultra-filtration in combination with the dissolved air flotation is also found to be effective, removing 70% TOC (Total Organic Carbon) and color. This process is also observed to be effective for the removal of heavy metals from the same effluent (Merrill et al. 2001). With the help of reverse osmosis, 80% BOD could be reduced. The use of ozonation is also observed to be useful both in terms of reducing the concentration of COD and toxicity of paper mill effluent. Such technique has also shown to reduce 85% of the effluent color (Sevimli and Sarikaya 2002, Freire et al. 2003,). The use of photon-fenton and wet-oxidation, in combination with ozone, or the advanced photocatalysis with O_2/TiO_2/UV, are also found to be quite useful for reducing the pollution load of paper mill effluent (Dufresne et al. 2001, Verenich et al. 2001, Perez et al. 2002, Hassan and Hawkyard 2002).

BIOLOGICAL TREATMENT UNITS

Most of the biological treatment units that are used for the treatment of paper mill effluent are activated sludge processes. Normally they operate at an OLR (Organic Loading Rate) of 0.07-0.21kg-BOD/m^3-day, and at a HRT (Hydraulic Retention Time) of 8-12hours. But the problems of poor settling of sludge have been reported in many cases of an activated sludge process during the treatment of paper mill effluent. These problems arise mostly due to the poor oxygen supply or low OLR or nutrient deficiency in the system. Though they can be encounter by adjusting the F/M (Food/Micro-organsims) ratio, or by the addition of certain chemicals like, chlorine, ferrous salts of lime etc. But practically the process becomes quite complicated in its function (Saunamaki 1997, Dalentoft and Thulin 1997, Yamamoto et al. 1991).

The COD removal efficiency of the activated sludge can be enhanced to 80%, if high-rate trickling filter or ozonation processes are introduced at its up-stream side (Kantardjieff and Jones 1997). But still there are several problems associated with the activated sludge process, when treating a high-strength industrial effluent, like that of the paper mil. Moreover, the toxicity removal efficiency of an activated sludge process is very low (Kennedy et al. 2000).

The other types of aerobic processes, like aerated lagoons, sequential batch reactor etc, have been observed to reduce 80% of the COD concentration of paper mill effluent. And 70% AOX removal was also noticed in a study performed by an aerated lagoon (Welander et al. 2000, Schnell et al. 2000). The toxicity removal from the paper mill effluent can be achieved by using bio-film reactors

(Asselin et al. 2000). The fungal treatment is observed to be effective for reducing 50% AOX from the paper mill effluent, at HRT of 2.0 days. But such a longer HDT makes the practical design of the system uneconomical. However, certain species of fungi, for instance P-Taeda, can be effectively used as a better pre-treatment option (Mendonca et al. 2002).

The tendency of using anaerobic process for paper mill effluent was started in early 70s. It has low energy input; comparatively fewer nutrients are requiring, and produce less amount of sludge. The two-stage processes, anaerobic-aerobic, are relatively more effective both in COD and sulfur removal from the effluent of paper mill (Chen et al. 2003). Anaerobic filter, up-flow sludge blanket (UASB), fluidized bed, anaerobic lagoon, and anaerobic contact reactors are the main available anaerobic treatment processes, which are widely used for the treatment of paper mill effluent. About 55% lignin removal was also reported by using anaerobic process, but since, the bleaching effluent of the paper mill consists of very low biodegradable fraction, and therefore, some researchers have suggested avoiding its application. Though, recalcintrent materials have also been identified in the pulping section effluent of the paper mill, which makes the anaerobic process difficult to operate. But still it is suggested by many authors to use anaerobic process for the treatment of paper mill effluent, as it comparatively reliable anc effective, and it can give more than 80% COD removal (Lettinga et al. 1991, Rajeshwari et al. 2000, Peerbhoi 2000).

In some studies, the anaerobic process was also modified for its better treatability performance, like stripping for sulfur contents, addition of an activated carbon etc. More than 70% COD removal has been observed by such modifications. In more recent study, the treatability performance of anaerobic process was enormously increased by the use of methanol, as an easily biodegradable substance and by the addition of an activated carbon with the digested sludge. The TOC and AOX removal of the technique was observed to be 90% and 75%, respectively, at an OLR of 4.8g-TOC/L-day and HRT of 16hrs. And the same technique was found helpful in the removal of 60% lignin from the paper mill effluent (Arshad et al. 2011, Arshad and Hashim 2012).

COMBINE AND TERTIARY TREATMENT UNITS

Generally, the combination of various treatment units is attempt to achive maximum treatability performance, and to polish the quality of the effluent before its final disposal. For instance, the combination of coagulation and wet-oxidation has shown to remove 50% COD and 75% lignin from the effluent of paper mill (Verenich et al. 2001). The combination of chemical-oxidation and ozone with bio-film or activated sluge process were also observed to be effective, it removed 80% of the COD (Schmidt and Lange, 2000). Jahren et al. (2002) worked on a sequential aerobic-anaerobic reactor, and found that 60% of COD can be removed from the effluent of paper mill. The combination of primary sedimentation tank and aeration basin has also shown to reduce 80% COD (Welander et al. 2000). In a study conducted by Shawwa et al. (2001), using a combine aerobic-anaerobic process the TOC and color removal efficiency from the paper mill effluent was observed to be 65% and 90%, respectively.

The most commonly used tertiary treatment units for the paper mill effluent are ultra-filtration, ozonation, adsoprtion and membrane technology. Chen et al. (2003) showed that the chemical coagulation, followed by dissolved air flotation and multimedia filtration are the best tertiary treatment options for the paper mill effluent, which gives final COD concentration of less than 100mg/L.

CONCLUSIONS

The disposal of untreated paper mill is one of the major environmental concerns, due to its high BOD, COD, AOX concentrations. The physcio-chemcial techniques are reliable in terms of their treatability performance, but they are very much expensive when applied to field scale measurements. And moreover, the handling and disposal of the sludge that is being produced during such processes also poses an additional problem. The aerobic processes are simple to operate, but the nutrients and energy requirements of such processes are comparatively more, and that makes them costly. Whereas, on the other hand, the anaerobic processes which has less inputs repquirements, and are easy to operate, seems to be more feasible for the treatment of paper mill effluent especially for the developing world. Furthermore, by using the latest available anaerobic technique of adding an esily biodegradable substance and activated carbon, highly acceptable quality of effluent could be produced, which can meet the requirements of available effluent disposal standards.

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