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APPROPRIATE TECHNOLOGIES FOR THE WASTE WATER TREATMENT IN DEVELOPING COUNTRIES

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Abstract

The pulp and paper industry, being one of the largest polluter of the water resources has to grow but at the same time it has to ensure the abatement of pollution of water resources. The conventional methods of treatment of waste water are associated with constraints of economy, availability of land and desired degree of treatment. The developing countries have to think of the processes which are free from the above constraints. In the recent past, a number of new technologies have been introduced and practised in the advanced countries.

This paper deals with a technologies like high rate anaerobic treatment, anaerobic-aerobic treatment, Sirofloc treatment, use of synthetic bacteria, aqua culture treatment and land treatment etc. These are briefly discussed with their advantages and disadvantages. Some of the processes are associated with generation of valuable bye-products besides they being economical and highly effective with respect to pollution abatement. A serious consideration must be given to adopt them in a developing country like ours as they are quite practical and feasible.

Introduction

The pulp and paper industry, a highly water internsive one, forms one of the major polluters of the water resources. With its rapid growth in our country, the necessity to maintain the water resources clean needs no emphasis. The industry has risen up to the expectation of the society in this respect in the recent past. However, the conventional methods of treatment comprising of sedimentation followed by a slow rate anaerobic or aerobic or a combination of both processes, being adopted presently or considered to be adopted presently or considered to be adopted in future, are associated with the constraints of economy, availability of land and desired effectiveness of the treatment. In the recent past, a number of new technologies have been introduced in the advanced countries and they are working well. Some of the internal control technologies like oxygen and ClO2 bleaching, zero effluent concept and use of synthetic sizing materials etc., though effective, cannot be adopted in a developing country like ours for a few decades to come for several of the constraints including economy. However, there is no reason why a few of the waste water treatment processes cannot be made applicable to our counditions because of them being highly cost effective vis-a-vis abatement of pollution of water resources.

An attempt is made to describe briefly a few of them in this paper along with their merits and demerits. They may be of special significance to small paper mills which are finding it difficult to adopt conventional methods of treatment for the reasons of economy and availability of space etc.

Modern Technologies

Some of the modern technologies are briefly discussed below incorporating the general principles only.

A. High Rate Anaerobic Treatment :

The principle behind this mode of treatment is that the organics get fermented/digested anaerobically i.e. in the absence of oxygen, generating bio-gas as well as clean waste water. There are two distinct phases in this operation. The first one comprises of acied fermen-mentation where complex organic materials are broken down mainly to short chain acids and alcohols with the help of acid forming bacteria. In the second phase, these products are converted to gases by methane forming bacteria. Both the phases proceed simultaneously producing mainly methane and carbon dioxide on the completion of the process. The process applicable to a waste water with a Chemical Oxygen Demand (COD) of around 1000 mg/l and above can work at a temperature range of 20-40^{0}C giving an efficiency of COD removal of 75-95% and generating bio-gas with 65-80% methane.

The major **advantages** of this process over conventional treatment are :

1. Low requirement of power
2. Generation of energy at low cost
3. Less production of bio-gas per unit of substrate utilised.
4. Low requirement of nutrients.
5. Higher organic loading potential
6. The storage of biological sludge during long shuts without seriously deteriorating its activities.

The process has the following **disadvantages,** in general :

1. Unsuitable for very cold and dilute waste water.
2. Production of methane sensitive to pH and concentrations of hydrogen peroxide and sulphur.
3. A post-treatment for odour may be required.

Against the conventional low rate anaerobic treatment system having long hydraulic retention time, the high rate anaerobic treatment systems are available where large quantity of bio-mass is retained in a relatively smaller reactor. About 20 full-scale installations are presently working in the pulp and paper industry throughout the world with the following types of reactors[1].

1. Contact Reactor : A closed tank with an agitator followed by a settling tank.

2. Upflow Anaerobic Sludge Blanket (UASB) Reactor : In this system, the waste water enters the bottom of the reactor to flow through layers of micro-organisms. The separation system is at the top of the reactor for separating gas, sludge particles and waste water. The system is suitable for a waste water with COD content of around 1000 mg/l and above.

3. Fluidized Bed Reactor : It is similar to above but with fluidized bed of micro-organisms attached on a carrier.

4. Fixed Bed Reactor : The waste water can pass upward or downward through a bed made of plastic material with a large specific area. The micro-organisms grow on the surface of the material and the void space in between the surfaces.

There are several agencies supplying the treatment systems based on the above concept. To illustrate the concept and process of this treatment, a typical illustration borrowed from a leading manufacturer is given in Fig. 1. It is using two stages fermentation approach. In the first contact reactor (C. R.), the organic matter is solubilized, hydrolised and converted into organic acids, ethanol, hydrogen and carbon dioxide by fermentative becteria. The second reactor transforms the intermediate products into

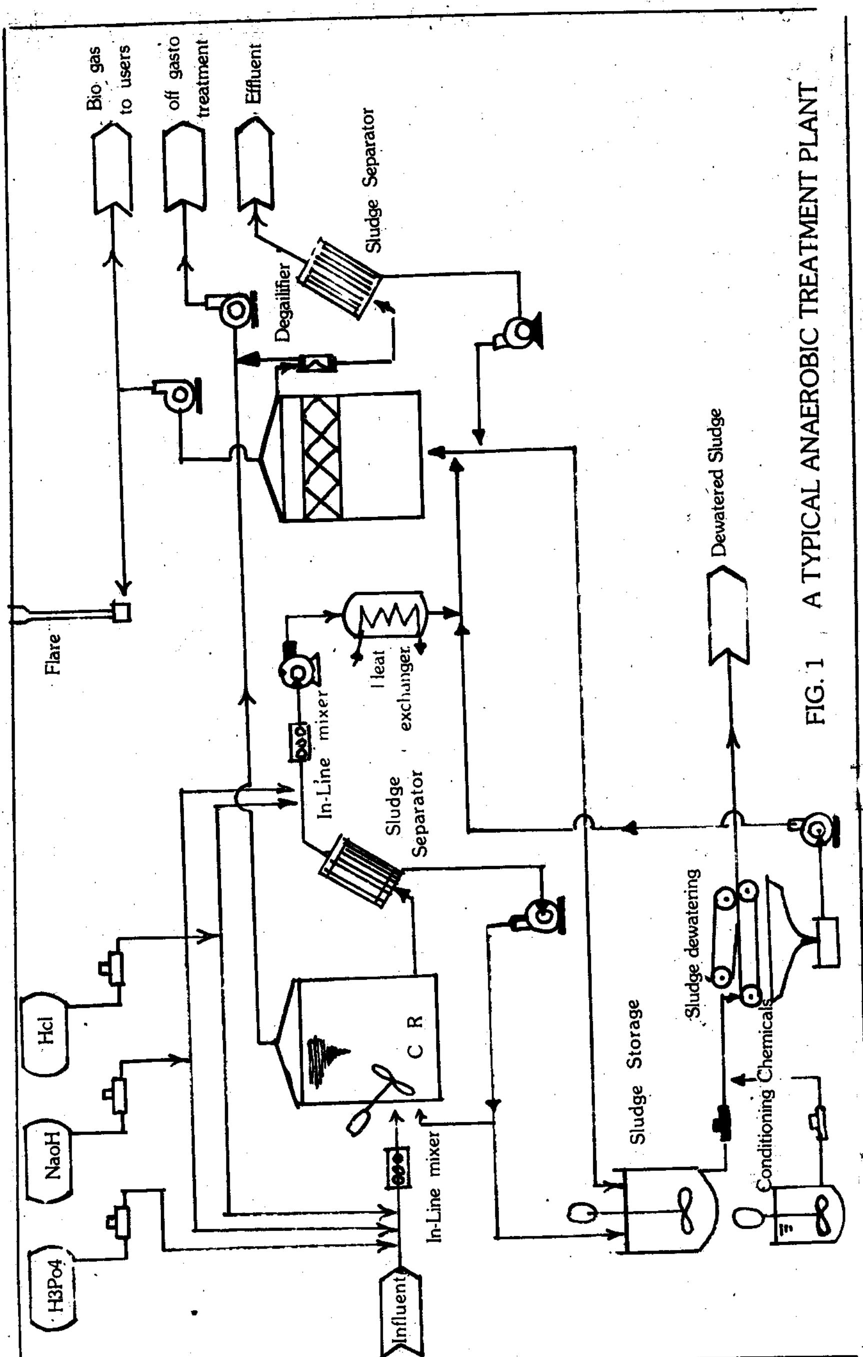

FIG. 1 A TYPICAL ANAEROBIC TREATMENT PLANT

methane and carbon dioxide by methane forming bacteria. It is expected to have a significant saving on the cost of the energy besides removal of toxic substances by 75–95% and thus making the waste water suitable for discharge to the stream[2].

B. High Rate Anaerobic-Aerobic Treatment

This method consists of high rate anaerobic treatment followed by anaerobic one[3]. A number of full-scale plants are in operation world over in various industries including half a dozen paper mills[4,5]. The anaerobic stage converts the main organic substances to methane and carbon dioxide and the aerobic stage removes the remaining contaminants. It produces a waste water which can be directly discharged to the receiving bodies.

Fig. 2 shows a typical anaerobic-aerobic treatment plant[3] where the waste water, after sedimentation, is pumped to two anaerobic reactors in parallel from where it passes in sequence to a de-gasifier, a thickener and an activated sludge system before being discharged. Pre-treatment can be varied as per the requirement. Some installations do noit have sedimentation[3]. The bio-gas produced meets a part of the energy requirement of the mills.

C. Sirofloc Treatment

This process developed by CSIRO, Melbourne can be used for the treatment of water as well as waste water[2]. It utilizes small particles of treated magnetite to remove impurities, odour and colour due to disssolved organic matter very efficiently and much more rapidly than any other method. The process has been briefly demonstrated in Fig. 3. In this treatment system, except a polyelectrolyte, no flocculant is used and the quick settling of magnetised particles eliminates the need for alarge sedimentation tank.

The process involves the use of finely divided (1–10 um) magnetite (Fe3O4), a naturally occuring substance, to absorb colloidal impurities under neutral or acidic conditions (pH 5–7). The surface of the magnetite particles gets positively charged and attracts negatively charged colloidal material. The magnetite waste water mixture is passed between the poles of a magnet causing the magnetite to form magnetic clumps which settle rapidly in a small clarifier leaving the waste water free from colour, odour and other impurities. Magnetite, containing absorbed colloids, is regenerated by reacting it with sodium hydroxide at high pH of 11.0. Under alkaline conditions, magnetite surface gets negatively charged and the absorbed material is repelled. It is then washed well and separated using magnetic drum separatons to make it ready for re-use.

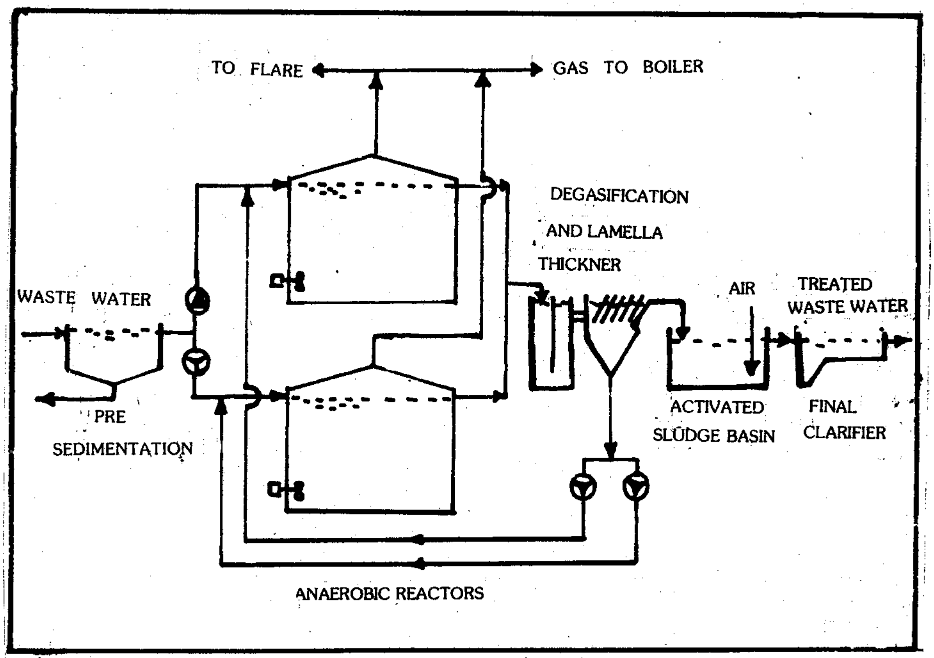

FIG. 2 A TYPICAL ANAEROBIC — AEROBIC TREATMENT PLANT

The BOD 5 values can be easily reduced from 300 to 20 mg/l with the help of 3-4 mg/l of a polyelectrolyte and 20 mg/l of Fecl3. It can also treat high volume dilute waste water to generate a small volume concentrated waste water rich in BOD5 and COD for anaerobic treatment. It is believed that BOD5, COD and colour can be generally removed to an extent of 75,80 and 95% respectively. The process is quite economical and only around 1/10th of land is required when compared to a conventional process. the work on the process is still in progress at CSIRO to improve upon further.

D. Synthetic Micro-organism Treatment

The biological treatments have so far been carried out with the help of naturally occuring micro-organisms only which come into contact with the waste water. Of late, Sibron Chemicals Inc., U.S.A. have synthesized Bi-chem series of bacteria to be added to the biological oxidation of industrial as well as municipal waste waters varying in type and quality in wide range[2]. The series covers about two dozen specialised strains of micro-organisms, both liquid and solid, being selective cultures designed to degrade individual contaminants of chemical wastes and metabolise them at an accelerated rate.

Bacteria are produced by a process of mutation followed by selection for specific de-gradation capability. By exposing these microbes during their manufacture to hostile conditions, that cause them to mutate, strains are produced that are more effective than natural occuring bacteria. The cultures are tailor made highly specialised mutant bacteria for a specific degradation property. They stabilise even COD constituting substances and generate a bio-mass of proper type and quality required for effective treatment of the chemical waste. Bacteria metabolise an grow through the action of enzymes an organic catalyst which are produced by the bacteria themselves. The enzymes help the chemical reaction to take place at ambient temperature sufficiently fast while alowing adequate growth to take place. Waste water treatment system functions better when a wide variety of micro-organisms desired for different functions are present and thrive in it, which are generally not present in a conventional waste water treatment system.

There are a number of cultures, each containing several strains of bacteria having an unique contribution to offer to the biological process, giving inter-related biological action. Depending upon the nature of the untreated waste water and the desired quality of the treated waste water one or more than one culture is selected and added to the biological treatment system. It can be effectively and economically used in any conventional biological treatment. Initially, the dosing is higher but gradually it goes down.

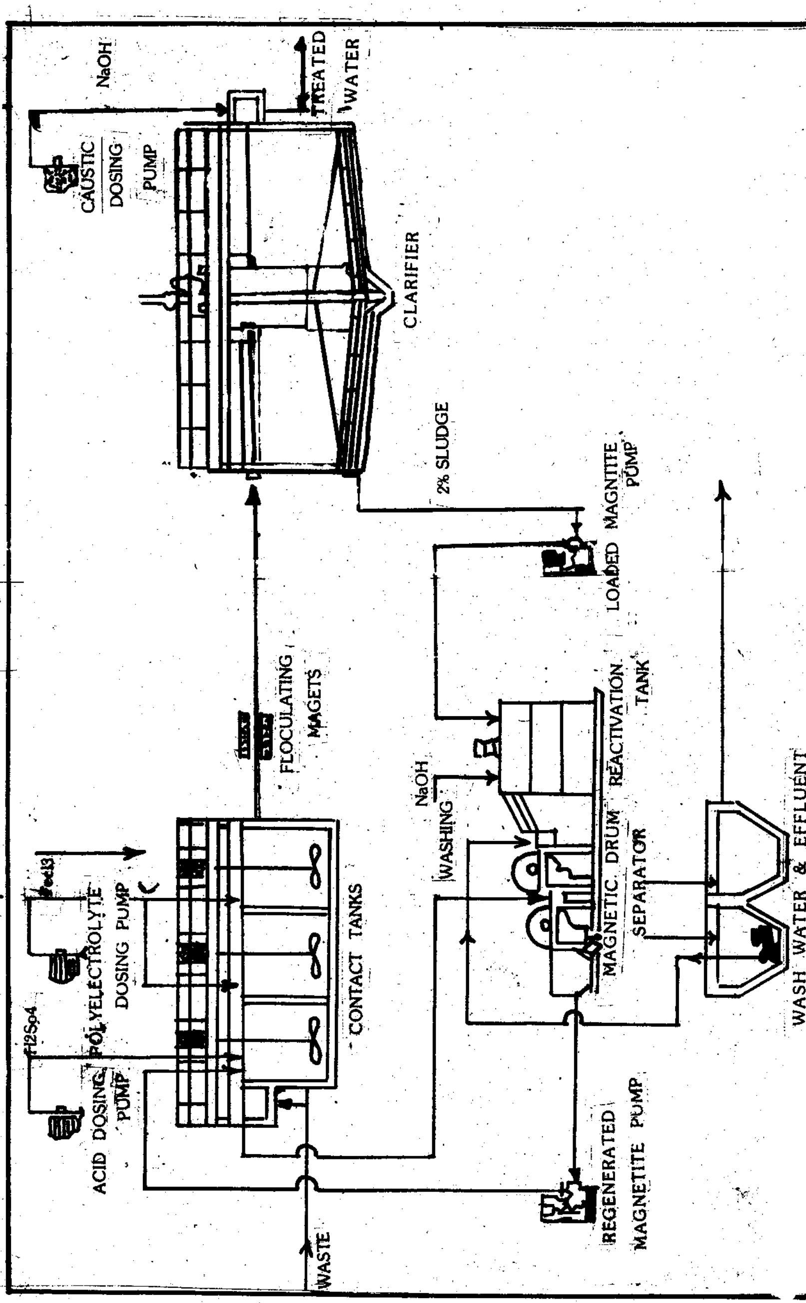

FIG. 3 'SIROFLOC' PROCESS FOR WASTE WATER TREATMENT

In the advanced countries, this system is getting very popular day by day for the simple reason that desired treatment can be imparted with the existing facilities for treatment with beneficial results. The process has the following advantages.

1. It is applicable to any industry and any type of waste water employing any type of conventional treatment system.
2. Various contaminants like BOD, COD, suspended solids, oil, grease, foam, colour, odour, phenols, amines, hydrocarbons - aliphatic, aromatic and chlorinated, lignins, cyanides, detergents, sulphur compounds, starches and proteins etc. can be reduced to a very low level.
3. It is available in dry and liquid form.
4. It is resistant to toxic materials, rather toxic materials get converted to harmless compounds.
5. It improves the cost effectiveness by savings in power, chemicals and waste handling. The sludge formation is very less.
6. Quick recovery time for bacteria following a shock load.

E. Aquaculture Treatment

Treatment of waste water employing an aquaculture has drawn the attention of scientists in the recent past. Some aquatic weeds like water hyacinth (*Eichhornia crassipes*) and Coontail (*Ceratophyllum demersum*) do a tremendous job in absorbing pollutants of all types, specially most of the toxic elements.

Water hyacinth

Water hyacinth, which creates hydrological as well as ecological problems, is proved to be a practical technology economically attractive and environmentally sound for treating waste water as per investigations carried out by National Space Technology Laboratories, U.S.A. It is highly prolific, reproduced mainly by vegetation and can double itself within a week when grown in warm nutrients enriched waste water. Experiments have shown that it has the ability to reduce the concentration of organics, minerals and other harmful metals like cadmium, chromium, mercury and silver etc. substantially (6–11). Trials are in progress at San-Diego, California for reclaiming potable water from municipal sewage[12,13].

Pulp & Paper Research Institute, Jaykaypur, Orissa[14] has carried out pilot scale study on the waste water from an integrated pulp and paper mill employing sulphate process. It was found that COD can be reduced by about 70/80% and colour to a great extent. One hyacinth plant can serve as a media for the treatment for a limited cycle only. Investigations show that it can be recycled for a few times only depending upon the quality of the waste water. Due to this phenomenon as well as rapid growth, regular harvesting of the old plants is essential.

Major uses of harvested plants are as under :

1. As it contains proteins and mineral, it can be used as an animal feed supplement.
2. It is a good source of organic fertilizer and soil conditioner because of high content of nitrogen and minerals.

Caution : The above two uses cannot be resorted to in case of water hyacinth containing toxic elements whose possibility is rare with the waste water of pulp and paper industry.

3. It can be successfully used for production of bio-gas which is now considered to be a viable alternative for petroleum and natural gas. 1 kg. of dried hyacinth can produce 374 litres of bio-gas containing 60–80% of methane. A pond of 1.0 hectare can produce 600 kgs. of dry plant per day equivalent to 2,39,400 litres of bio-gas.

Apart from the above, the other advantages of using this system are :

1. Water hyacinth survives in a wide range of pH i.e. 4–10 and brings down the final pH of the waste water around neutral, irrespective of the initial pH.
2. BOD5, COD, dissolved solids, colour, toxicity, metals and organic nutrients etc. are removed to a large extent which is not possible otherwise in any other conventional treatment process.
3. The treatment can be given in a batch or continuous system.

The following are the constraints and dis-advantages of the system :

1. Large area of land is required. Obviously, its availability and economical cost limits the adoption of this process.
2. Considerable nuisance of mosquitoes and odour.
3. The outflow has to be ensured free from the plant or its parts to avoid its wild growth in the receiving water resources.

Coontail

A study on Coontail (*Ceratophyllum demersum*) reveals that it can remove BOD, phosphorous and ammonia – the indicators of eutrophication, by over 95%[15]. It also purifies sullage to a very high level and requires less frequent harvesting of the plant. The work is still in progress foir industrial waste waters. However, based on whatever results are available, it is believed to be a better media of treatment than water hyacinth, even for the waste water from the paper industry.

F. Land Treatment

The use of soil as a treatment system has been practised in the past not only in our country but in several parts of the world. Of late, it has been gaining considerable importance because of this being an easy mode of disposal of the waste water coupled with the complete prevention of pollution of the surface water. The waste water is used as a continuous or supplementary source of irrigation water. However, the decision to use it as irrigant is influenced by the location of the indusry, its characteristics as well as the type of the soil and the crop grown etc. Besides, the seasonal increase in irrigational practices where low flow of surface water coincides with the seasonal increase in irrigation water, advanced agricultural practices advocating supplementary irrigation at various stages of the plant growth of derive the best advantage, to meet the drought conditions, rising cost of water and difficulties in waste water treatment by conventional methods have been very much responsible for this approach.

Based on the work carried out in the country as well as outside and recommendations available from the experts coupled with the practical experiences, the waste water from the industry is generally believed to be quite suitable for irrigation of the crops as well as plantation. Leaving aside the researches carried out in foreign countries and experience gained therein extensive study has been carried out in our own country at Orient Paper Mills, Amlai and J. K. Paper Mills, Jaykaypur. Besides, the experience of successful irrigation has ben gained at Seshasayee Paper & Boards Ltd., Pudumji PUlp & Paper Mills, Gaurav Paper Mills and Mysore Paper Mills Ltd. etc. (16–20).

There are several guidelines and specifications available to take a decision with respect to a particular waste water to be used as an irrigant. The basic parameters required to be studied for with respect to a particular soil and crop are Electrical Conductivity (EC), Dissolved Solids (DS), Sodium Absorption Ratio (SAR), Exchangeable Sodium Percentage (ESP), Boron (remote chance for its presence in appreciable quantity) and Residual Sodium Carbonate (RSC) etc. Obviously, the degree of treatment of the waste water will vary to make it suitable for irrigation under specific circumstances.

The organics, sodium and calcium salts and negative value of RSC present in the waste water play an important and beneficial role in improving the characteristics of the soil as well as th yield and quality of the crop in most of the cases. The waste water from a large intergrated pulp and paper mill chemical recovery unit can be used after primary clarification in many of te cases. However, it has to be a composite waste water and not the segregated one. Highly concentrated waste water from pulp mill or small paper mills with pulping unit but without chemical recovery will require partial biological oxidation with adeuate dilution. BOD does not appear to be of much significance in case all other chaacteristics are well in order. Similarly, the content of sodium is not important provided SAR is within limits.

Often, the apprehension of sodium hazard to or sodium poisoning of the soil due to high sodium slats leading to high SAR or high ESP is expressed in certain quarters not well familiar with the waste water of the pulp and paper industry. This apprehension does not hold good in well permeable soils. Even, in the adverse circumstances on this account, after long use of waste water, the situation can be brought safely under control by adopting soil amendment/reclamation practices of adding calcium slats like calcium chloride, gypsum and dolomite etc. either to the waste water or the soil. This will bring the damaged soil to its original condition. In case of further necessity, modern farm and/or soil management practices like surface drains, frequent irrigation with reduced quantity of waste water, rotation of crops and manuring to compensate for nutrients can be resorted to. It is beyond the scope of this paper to deal with the mechanism by which irrigation of the crops with the waste water from our industry results in higher yield and better quality of the crop. However, briefly it can be said that the use of waste water has useful role to play in changing the characteristics of the soil for better growth of the plant, mainly on account of organics, nutrients and sodium present in it as well as timely and adequate irrigation, which otherwise is not possible in many cases.

Often, the question is asked with regard to the characteristics of the sub-soil water in the region of waste water irrigation. By all studies available so far, the apprehension appears to be incorrect. It is expected that BOD load in the waste water is stabilised by soil microbes by the time it reaches the sub-soil water. The lignin which is not readily bio-degradable adds to the soil organics. Also, the lignin present in waste water reacts with Ca^{++} released or exchanged by Na^{+} to form an insoluble calcium lignate precipitate and is thus retained by the soil. It is strongly believed that the use of waste water from pulp and paper industry will not pollute the sub-soil wafer.

Conclusion

It can be concluded that a few of the recent technologies developed and proved to be more economical and effective for the treatment of waste water in several advanced countries are easily adoptable in developing countries like ours. They must be seriously considered to replace the conventional processes of treatment associated with several constraints. This will go a long way to help the Indian Paper Industry in several respects to combat the menace of pollution of surface waters. In addition to large integrated paper mills, even small paper mills can take the advantage of it. Needless to say that the efforts in this direction need an intergrated approach as well as active cooperation from all concerned i.e. the government, the industry, the pollution regulating authorities and especially the indigenous manufacturers of the plant and machineries. As a few of the technologies will have to be imported presently, the existing situation of the industry demands that the equipments and he technology is available indigenously in order to save the valuable foreign exchange as well as high capital expenditure. Some of the manufacturers of plants and machineries can take a lead in this direction with the support of the industry. The recurring expenditure, in any way, is expected to be very much reduced in addition to several financial gains and complete abatement of water pollution.

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