REFEREED PAPER

NEW TECHNIQUE FOR EFFLUENT TREATMENT IN SULPHITATION SUGAR FACTORIES

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Abstract

The sugar industry in India has a vital role in economic and rural development. However, effluent generated from this industry has a high pollution load and thus the sugar industry in India has been kept in the 'Red Category', i.e. an industry posing a threat to the environment. As per the latest legislation laid down by the pollution control authorities in India, the maximum effluent discharge limit is 200 litres/ton of cane. About 50% effluent generated at a sugar mill is from spray pond overflow or process cooling tower blow down. The average sugar production in India is about 25-28 million tons annually, and almost 95% sugar is produced by double sulphitation process. Waste water generated in sulphitation sugar factories, particularly, spray pond overflow/process cooling tower blow down contains sulphate of approximately 800-1 200 ppm, which imposes difficulties in treatment of effluent by Activated Sludge Process (ASP) adopted by most Indian sugar factories. ASP is based on the activity of bacteria which works under aerobic conditions and decomposes organic matter by producing carbon dioxide and ultimately reduces the pollution load. The presence of sulphate suppresses/deactivates the activity of bacteria, thus making it difficult to achieve the desired parameters of treated effluent as per legislation. A new physico-chemical technology has been developed and successfully implemented in commercial sugar factories. The new system gave excellent results in reducing the sulphate content by 40-50% and finally the quality of treated effluent could be maintained as per the requirement for surface discharge/mixing in water bodies.

Keywords: double sulphitation, spray pond, sulphate content, physico-chemical technology, activated sludge process

Introduction

Water is an essential part of all living organisms, and plays a most important and valuable role in the natural cycle. Among the world water availability, only 3% fresh water is available on the earth (Kumar and Swami, 2015). In the available fresh water sources, entry of pollutants has been significantly increased from industries and domestic/anthropogenic activities. In this scenario the conservation strategies play an important role in the conservation of fresh water bodies as well as water quality. Significant quantities of fresh water are consumed in the production process that is followed by the sugar industry and this process results in higher generation of effluent as well.

Sugar is one of the most important substrates for human diet and it is an essential part of human life. Sugarcane is a valuable crop for bio-products because it produces sugar, bagasse which provides energy, and molasses which is used for production of alcohol. Sugar is produced in approximately 115 countries of the world. Of these, 67 countries produce sugar from sugarcane, 39 from sugar beet and nine countries from both sources. (Poddar and Sahu, 2017). Top countries of the world that produce sugar from cane are Brazil, India, Thailand, Australia, China and South Africa. In other words, about 70% sugar is produced from sugarcane worldwide and India is the second largest producer. In 2016-17, Indian sugar factories produced 20.26million tons of sugar by crushing 193.43 million tons of sugarcane at an average recovery of 10.48% cane. Sugar is one of the most significant agricultural products, and the sugar industry is vital to the Indian economy. The sugar industry has created a significant socio-economic impact on rural agro-based economy and in particular the Indian economy in general.

The Indian sugar industry produces white sugar by following a raw-refined route and more than 95% of the direct consumption plantation white sugar is produced by a double sulphitation process. Effluent generated by factories using the raw-refined route can be easily treated and made suitable for surface discharge/mixing in water bodies as per the norms enforced by pollution control authorities in India. However, this is not the case with effluent generated by double sulphitation factories. A major factor for this is the presence of sulphate in considerable quantities in effluent produced which poses difficulties in the treatment process. Most of the double sulphitation sugar factories employ an Activated Sludge Process (ASP) for treatment of effluent, which works on the activity of aerobic bacteria. The presence of sulphate in considerable quantities suppresses or even stops the activity of these bacteria, resulting in the poor working of effluent treatment plants and making it difficult to maintain the desired parameters of finally treated effluent as per directions of pollution control authorities. Due to this problem, most of the sulphitation sugar factories were not treating the spray pond overflow/process cooling tower blow down and disposing of it directly into the water bodies, which is very hazardous not advisable from the water conservation point of view. Scientists (Chao-hai *et al*., 2007) have discussed the ill effects of the presence of sulphate in industrial effluent treatment process by two-phase anaerobic digestion process. The present study has been carried out with the aim of developing a sustainable economic physico-chemical treatment process for effluent of sugar factory following the double sulphitation process for production of direct consumption plantation white sugar so as to achieve the norms listed in Table 1.

Table 1. Norms for effluent discharge from sugar factories in India.

S.No	Parameters	Norms for discharge
1	pH	5.5-8.5
2	COD mg/l	250
3	BOD mg/l	100 for disposal on land 30 for disposal in surface waters
4	Oil and grease mg/l	Less than 10
5	TSS mg/l	100 for disposal on land 30 for disposal in surface waters
6	TDS mg/l	2 100
7	Final waste water discharge	200 l/ton of sugarcane crushed
8	Emissions	The particulate matter emissions from the stack shall be less than 150 mg/m^3

Quantity and quality of waste water

Significant quantity of fresh water is consumed in conversion process of sugarcane to sugar by the double sulphitation process. However, now the sugar factories in India have gone for adoption of the latest techniques to minimise the consumption of fresh water as per the directions of pollution control authorities, and also due to diminishing availability of fresh water as a result of continuous drought situations in some parts of the country. According to latest guidelines issued by the Government of India, as mentioned in Table1, the maximum discharge limit for treated effluent by sugar factories is 200 l/t of cane crushed. Data collected from 10 sugar factories producing sugar by the double sulphitation process (Table 2) show that spray pond/cooling tower overflow constitute approximately 40-50% of the total effluent generation. The figures for fresh water were observed also to be vary widely, reflecting on water conservation measures taken and also depending on the configuration of steam generation units.

Table 2. Data on effluent generation by sulphitation sugar factories.

S.No	Plant capacity (TCD)	Fresh water consumption (l/t cane crushed)	Spray pond/process cooling tower blow down(l/t cane crushed)	Total effluent generation(l/t cane crushed)
1	2 500	152.80	67.98	148.70
2	5 000	127.00	85.00	178.50
3	3 500	200.00	133.00	276.00
4	6 500	100.30	92.50	192.00
5	4 800	134.00	85.00	193.00
6	4 200	75.50	115.00	190.00
7	9 000	286.00	92.00	194.00
8	10 000	71.30	87.30	168.00
9	12 500	173.00	83.00	175.00
10	16 000	255.00	83.00	186.00

As per the most common process (ASP) followed by the Indian sugar industry for effluent treatment, the spray pond overflow is mixed with the effluent generated from other streams and treated. Due to the presence of sulphates in significant quantities, the formation of various sulphates and blackening of water occurs (Bhuvaneswari *et al*., 2013) during the retention period, which suppresses the activity of aerobic bacteria and consequently disturbs the entire process of effluent treatment. For this reason, it was inferred that if the spray pond overflow was treated separately at the first stage for reduction of sulphate content and then mixed with other effluent at a later stage for further treatment, then the ill effects of sulphate on the treatment process could be avoided. Samples of common effluent and spray pond overflow/process cooling tower blow down were collected from commercial sugar factories and analysed. The average characteristics of spray pond overflow/ cooling tower blow down and common effluent is presented in Table3. In the present study, all the analysis work was carried out as per standard methods of waste water analysis (APHA, 2017) and with AR grade chemicals in the research laboratory of the National Sugar Institute, in Kanpur, India.

Table 3. Characteristics of Spray Pond Overflow/Process Cooling Tower Blow Down and Common Effluent.

S.No	Parameters	Spray pond/process cooling tower overflow	Combined effluent
1	pH	5.4-5.8	5.6-6.10
2	TDS mg/l	1 500-1 800	2 000-3 000
3	Sulphate mg/l	800-1 250	600-1 000
4	COD mg/l	400-800	600-1 000
5	BOD mg/l	150-200	250-400
6	Oil and grease mg/l	Less than 1.0	25-30
7	TSS mg/l	30-50	150-250

Existing method of treatment

As mentioned in the earlier paragraphs, In general, Indian sugar factories follow ASP (Figure 1) for treatment of waste water. Although this process holds good for treating the effluent of sugar factories following the raw-refined route, effluent from sugar factories following the double sulphitation process needs some pre-treatment before being subjected to conventional ASP because of the presence of sulphates. In this process, pH of the effluent is raised with the help of milk of lime up to 9.0-9.5, which facilitates the precipitation of suphate as gypsum as per following chemical reaction.

$$Ca(OH)_2 + 2H^+ + SO_4 \Rightarrow CaSO_4.2H_2O$$

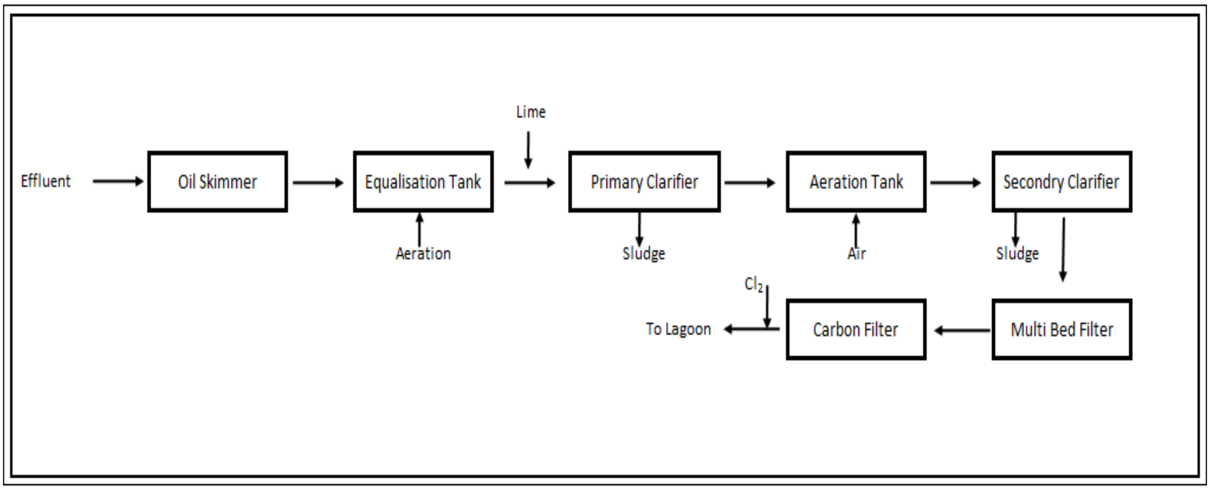

Figure 1. Activated sludge process.

Laboratory experiments

Spray pond overflow/cooling tower blow down samples collected from commercial sugar factories were analysed for different parameters, viz. BOD, COD, pH, TDS and TSS and pre-treatment techniques were applied. Analysis results of the spray pond overflow/cooling tower blow down water samples revealed the presence of varying amount of sulphate (600-1200ppm).Therefore samples were separated into two categories, viz. containing sulphate up to 800 ppm (type1) and more than 800 ppm (type2). For treatment of type1 samples, pH of the water was raised with milk of lime of about 5°Be and polyacrylamide based flocculent was applied at 3-5 ppm dose and allowed to settle in a measuring cylinder. After settling, the decanted liquor was analysed for the same parameters. The dose of milk of lime was optimised at 10.5 for this category of water. The results of these experiments are presented in Figure 2.

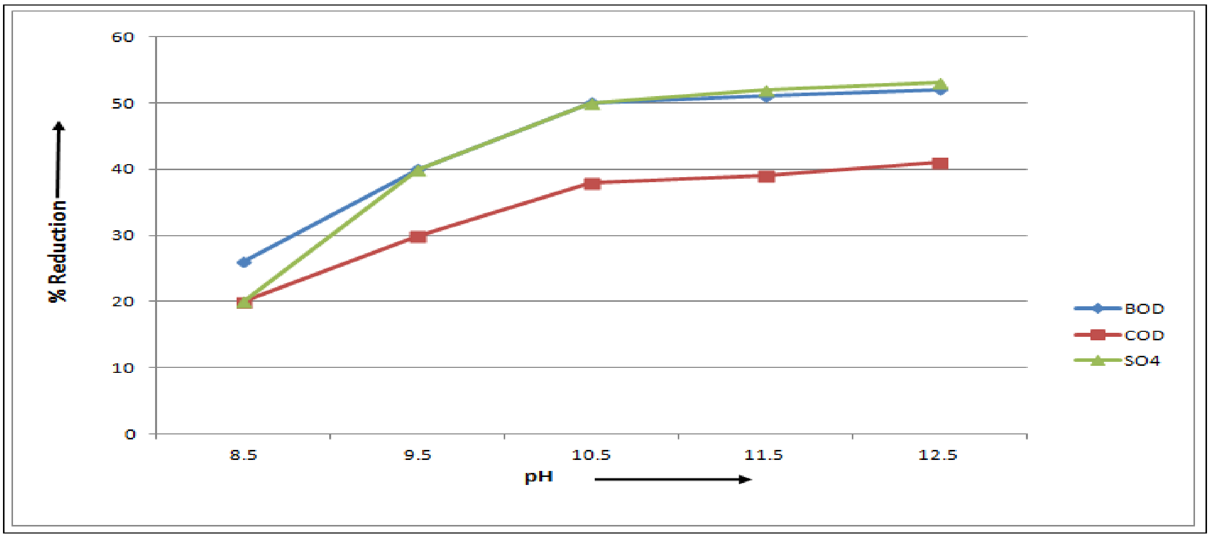

Figure 2. Percentage reduction in pollutants, viz biological oxygen demand (BOD), chemical oxygen demand (COD) and sulphate content (SO_4) by using a lime at different pH (type 1).

Similarly, the treatment of type2 samples was done by raising the pH with milk of lime of 5° Be and applying a poly aluminum chloride dose at 15 ppm. The dose of milk of lime was standardized at 11.5 for this type of waste water. The treated sample was allowed to settle for 30 min and decanted liquor was analysed. Quantity of lime was increased slowly as reduction in quantity of pollutants was observed, and optimisation of chemical doses was done. Data obtained on reduction in pollutants against the quantity of lime applied is presented in (Figure 3).

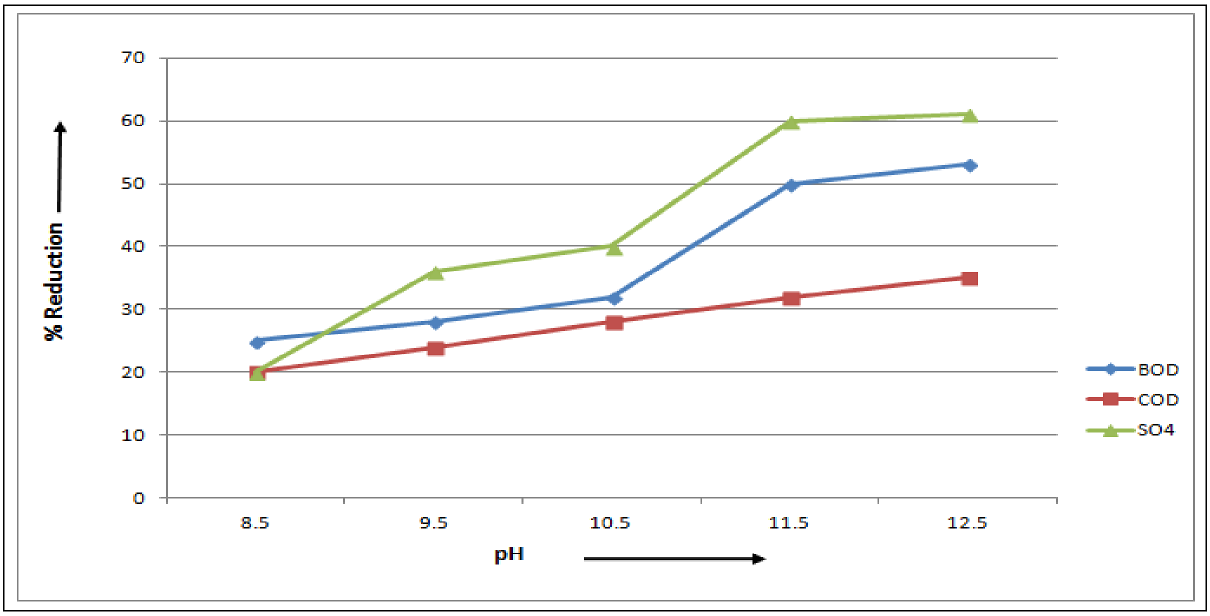

Figure 3. Percentage reduction in pollutants, viz. biological oxygen demand (BOD), chemical oxygen demand (COD) and sulphate content (SO_4) by using a lime at different pH (type 2).

Results of the above experiments revealed that the pH of spray pond overflow/process cooling tower blow down is required to be raised to 10.5 and 11.5 for the samples containing sulphate up to 800 ppm and more than 800 ppm, respectively, in place of pH 9.0-9.5 generally maintained by sulphitation sugar factories in equalisation tanks during effluent treatment.

Trials at commercial sugar factories

Based on the results obtained during the laboratory experiments, two different physico-chemical treatment processes were tried at two different commercial factories producing direct consumption plantation white sugar by the double sulphitation process.

Trial1

A commercial sugar factory situated in the western part of the Uttar Pradesh province in India was selected for the trials on treatment of spray pond over flow of type1. The process is based on separate treatment of spray pond overflow and then mixing the treated overflow with other effluents for further treatment by conventional ASP. The details of the plant and process, and other parameters are given below.

Crushing capacity 7000 t cane per day
Process followed Double sulphitation
Total quantity of effluent 1316 m^3per day (188 l/t sugarcane crushed)
Spray pond overflow 530m^3per day (76 l/t of sugarcane crushed)

Quantity of sulphate 600-800 ppm
Process of effluent treatment Activated Sludge Process
Chemicals used Milk of lime (5°Be) and commercially available flocculants.

Spray pond overflow was separated from other streams of effluent being generated in the sugar plant and the same was sent to a reaction tank of 10 cum working volume fabricated by stainless steel. Total reaction time optimised was around 20 minutes by a trial and error method. Arrangements for continuous dosing of lime and flocculants were made and the arrangement of aeration from the bottom was carried out with the help of compressed air. Milk of lime was added to a pH of 10.5 and flocculent was added at 5 ppm. The treated water was then allowed to settle in a lamella clarifier for about 30 minutes. A flow diagram of the pre-treatment process is shown in Figure 4).

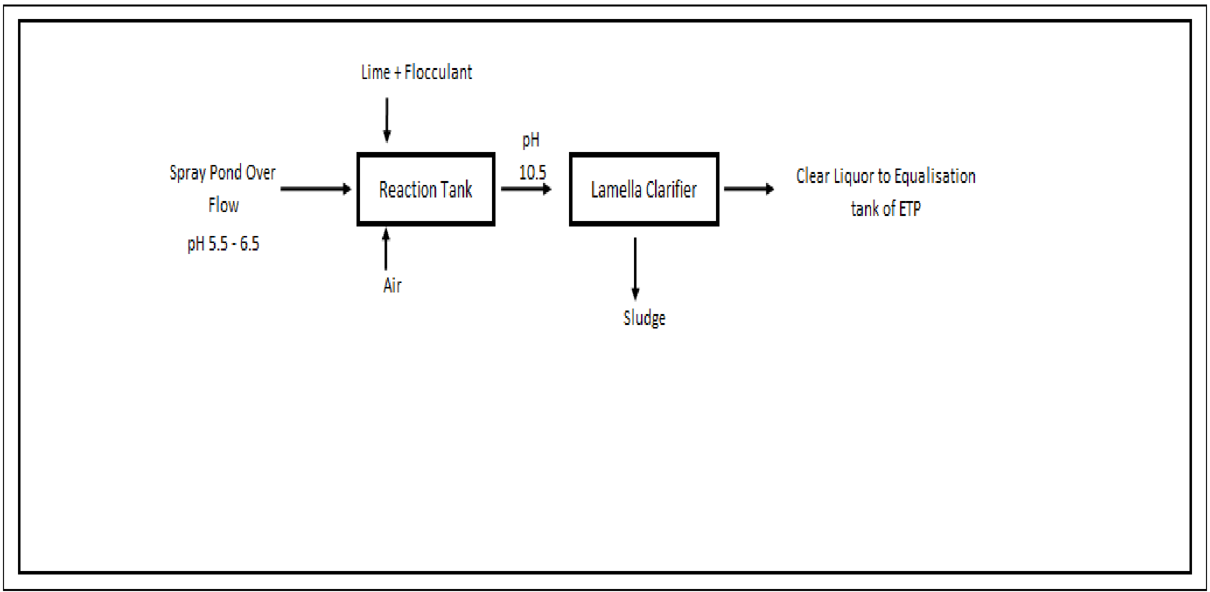

Figure 4. Spray pond overflow treatment, Trial 1.

Treated decanted water was taken from the clarifier and mixed with effluent from other streams in the equalisation tank for treatment by ASP. Sludge was taken from the bottom of the lamella clarifier and sent to the sludge drying beds. A process flow diagram is given in Figure 4, and analysis results of treated and untreated spray pond overflow water are given in Table4. Laboratory analysis data with regard to treated final effluent from the sugar factory is given in Table 5. The data presented is the average of four sets of analysis carried out at the factory site.

Table 4. Laboratory analysis data of spray pond overflow (type1).

S.No	Parameters	Untreated water	Treated water	% reduction
1	pH	6.25	10.50	-
2	BOD mg/lit	220	150	32
3	COD mg/lit	550	400	27
4	TDS mg/lit	897	970	-
5	SO_4 mg/lit	680	430	40

Table 5. Laboratory analysis data of treated final effluent (trial 1).

S.No	Parameters	Analysis data
1	pH	7.4
2	COD mg/l	224
3	BOD mg/l	28
4	Oil and grease mg/l	7.0
5	TSS mg/l	24

Trial 2

Another commercial sugar plant situated in Uttar Pradesh province in India was selected for trials on treatment of spray pond overflow of type-2, i.e. containing sulphate more than 800 ppm. In this case also, separate treatment of spray pond overflow was preferred and the treated spray pond overflow was then mixed with other streams of effluent for treatment in the conventional manner. Details of the sugar plant and the process followed are given below.

Crushing rate 4 800 t cane per day
Process followed Double sulphitation
Total quantity of effluent 935 m^{3}per day (195 l/t of sugarcane crushed)
Spray pond overflow450 m^3 per day (94 l/t of sugarcane crushed)
Quantity of sulphate 1 000-1 150 ppm
Process of effluent treatment Activated Sludge Process
Chemicals used Milk of lime (5° Be) and poly aluminum chloride.

In the second process, after separating the spray pond overflow from other streams of waste water, the overflow was subjected to chemical dosing in a reaction tank. Milk of lime was added up to11.5 pH and poly aluminum chloride was added at 15-20 ppm per dose. Diffused air was applied from bottom. After allowing the reaction to complete for 20 minutes, the settling was carried out in micro settlers for about 35 minutes. The flow diagram for this pre-treatment process is presented in Figure 5.

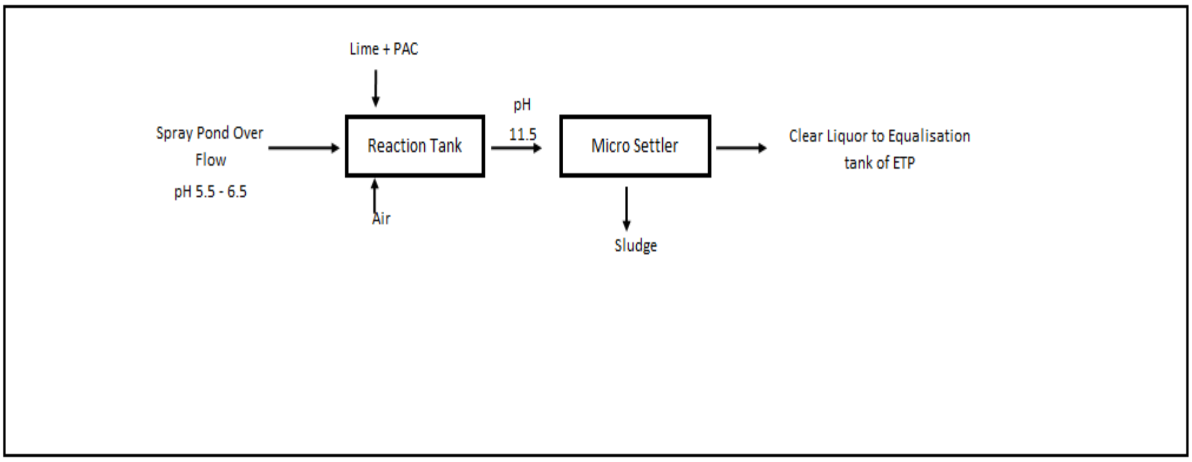

Figure 5. Spray pond overflow treatment, trial 2.

Decanted liquor from the micro settlers was mixed with effluent in an equalisation tank of effluent treatment plant for further treatment by conventional ASP. Sludge was taken from the bottom of the micro settlers and sent to sludge drying beds. A flow diagram for this pre-treatment process is given in Figure 5, and analysis results of water before and after treatment is given in Table6. The laboratory analysis data with regard to treated final effluent is given in Table7.

Table6. Laboratory analysis data of spray pond overflow (type2).

S.No	Parameter	Untreated water	Treated water	% reduction
1	pH	5.8	11.50	-
2	BOD(mg/l)	280	140	52
3	COD(mg/l)	670	450	41
4	TDS(mg/l)	770	1050	-
5	SO4(mg/l)	1180	470	50

Table7. Laboratory analysis data of treated final effluent (Trial2).

S.No	Parameters	Analysis data
1	pH	7.6
2	COD mg/l	160
3	BOD mg/l	24.6
4	Oil and grease mg/l	6.8
5	TSS mg/l	25.6

Other prerequisites

In order to achieve the desired results and to have consistency in the results as well, certain other modifications were carried out and capacities at various unit operations were optimised/standardized, viz:

(i) Provision of diffused aeration system in place of surface aeration in the aeration tank. The equalisation tank was also provided with a diffused aeration system.
(ii) Retention times of 4 h and 48 h were maintained in the equalisation tank and aeration tank respectively. Similarly, for ASP, retention times of 4h and 6h were ensured in primary and secondary clarifiers, respectively.
(iii) Effective removal of oil and grease was ensured and effective screening was carried out to remove maximum bagacillo from the waste water of the mill house.
(iv) MLSS (Mixed Liquor Suspended Solids) content of 2 500-3 000 mg/kg was maintained in the aeration tank.
(v) Tertiary treatment units, i.e. multigrade filters and activated carbon filters, were installed, having a contact time of at least 15 minutes.

Conclusion

The study conducted indicated that in plantation white sugar factories following double sulphitation process, pre-treatment of spray pond overflow/process cooling tower blow down may be carried out separately for removal of sulphates so as to have the desired efficiency of Activated Sludge Process of effluent treatment. Selection of pre-treatment methods and process parameters to be maintained will depend on the characteristics of the spray pond overflow/process cooling tower blow down. This will ensure and help in the better working of the effluent treatment plant and achieving the norms consistently as per pollution control authorities for finally treated waste water.

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