Process intensification of effluent treatment plant

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***Abstract*—Industrial effluent may be defined in the broadest terms as the liquid waste generated by any industrial, processing or manufacturing activity. Disposal and treatment of effluent is of concern because releasing untreated effluent into water sources leads to many environmental problems. Effluent quality is decided by many parameters, chiefly the pH, TSS and COD values. Present treatment in the industry for reducing the above mentioned parameters involves neutralization, settling, clariflocculation and aeration. The chief drawback of these techniques is their batch type operation, large capital and operating costs and huge floor space requirement. The aim of this research was to prove that effluent can be treated in continuous operation and at the same time achieve better results than those achieved in a similar batch operation. Additionally another novel feature of this research was to prove that two unit operations which are used in effluent treatment i.e. filtration and aeration can be combined in a single unit. A unit was thus fabricated on a laboratory scale which combined elements of both filtration and aeration operations. The entire assembly was optimized for continuous operation and tested with various effluents. The parameters of the outlet effluent from the unit (pH, TSS, COD) and the resulting data was analyzed, following which our initial estimates regarding the efficiency of the system was validated. Near complete TSS removal was achieved along with 39-45% reduction in the COD values.**

***Index Terms*—effluent quality, pH, TSS, COD, continuous, single unit, efficiency**

I. Introduction

Industrial effluent is the wastewater generated by any industrial activity. An industrial activity is any process that involves creation of any object or service for profit. All industries, no matter how large or small produce effluent that must be neutralized and made safe for disposal into water bodies.

When untreated effluent accumulates and is allowed to go septic the decomposition of the organic matter in the effluent occurs and leads to production of environmentally harmful products and malodorous gases.[1]

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In addition effluent may contain pathogenic microorganisms that dwell in the human intestinal tract. Effluent from industries may also contain toxic compounds or compounds that potentially may be mutagenic or carcinogenic.[2]

Some of the compounds present in an industrial effluent may potentially undergo an oxidation reaction when exposed to the dissolved oxygen (DO) in water. This reduces the available DO in water, potentially risking the life of aquatic life[3]. For these and many other reasons too lengthy to mention here, industrial effluent must be treated and rendered safe for discharge into large water bodies. Effluent quality is discussed in terms of parameters like pH, total suspended solids (TSS) and chemical oxygen demand (COD) [4].These are the so called critical parameters on which effluent quality is judged and standards relating to effluent treatment and discharge are set. For instance the central pollution control board (CPCB), India has mandated that, for treated effluent discharge in salt water bodies the pH value must lie between 6 to 8.5.The maximum permissible values for COD and TSS are 250 mg/l and 200 mg/l respectively[5].Industrial effluents are normally treated in large common effluent treatment plants (CETP) where primary and secondary treatment of effluent is effected. pH of the effluent is controlled and adjusted to within the limits as specified by the environmental regulatory body. Following pH neutralization effluent is pumped to a clariflocculator where flocculating agents like alum are added. The effluent is allowed to stagnate for some time in the flocculation tank[6]. This allows sufficient time for the suspended solids present in effluent to settle at the bottom of the tank. The supernatant liquid effluent is then drained off from the tank and passed into a aeration tank where air is normally blown into the collected effluent. This oxidizes the oxidizable compounds in the effluent and reduces the COD value of the effluent[7]. CETP's can handle effluents to the tune of a few million liters per day (MLD) but they have some intrinsic drawbacks[8].

The capital cost for construction of a CETP is very high and so are the associated operating costs[9]. CETP's by necessity have to be located near or in the industrial area they serve, thus occupying land in and already congested industrial area. Considering these problems, a probable solution is to reduce the values of the critical parameters of an effluent at its source of generation itself. This would necessitate the use of a robust and highly adaptable effluent treatment system. The said system would have to handle any change in the concentration of the inlet effluent to it without sacrificing its efficiency. A minimum requirement is to be able to reduce the TSS and COD values to within acceptable limits.

ISSN: 2278 – 7798

II. FABRICATION DETAILS

The system was fabricated and optimized for laboratory usage. It included an continuous stirred tank reactor (CSTR), a sand bed type filter for sludge removal and an aeration cum filtration unit. The performance of the aeration cum filtration unit was the focus of this research. The CSTR had a capacity to neutralize 10 liters of untreated effluent and was fabricated from aluminium sheets of 2 mm thickness. A 3 bladed propeller type stirrer affixed to a motor capable of 4000 RPM was attached to the reactor. The sand bed was fabricated from HDPE and was prepared as per the US EPA design guidelines.

A catchment vessel was provided below the bed and a small submersible pump was placed in the said vessel to provide sufficient flow rate for the filtration operation. The filter cum aeration unit was envisioned to be used in a continuous flow operation and was designed accordingly. It's was fabricated from PVC. PVC was so chosen to allow ease of fabrication, lightness of weight and a good corrosion resistance. The filter media chosen was a polypropylene candle type filter of 3 inch diameter and 1 inch wall thickness. The filter had a mean pore size of 5 microns. A clearance of about half inch was provided between the outer wall of the filter and the inner wall of the filter casing.

The aeration zone was located below the filtration zone and featured a side entering 4 bladed stirrer attached to a motor capable of 1000 RPM. This was done to ensure the effluent stream continuously emerging from the filtration zone was broken up into miniature droplets which provided better residence time and surface area for aeration. Compressed air was blown into the aeration zone via small tubes. All supports were fabricated from mild steel (MS) and half inch diameter tubes were used in interconnections.

Image 1 :- The assembly as used in experimental work.

Image 2 :- The filtration cum aeration unit as used in the experiment

III. EXPERIMENTAL WORK

Untreated effluent was initially passed into the CSTR at a flow rate of around 1.2 liters per minute (LPM) and after the stirrer was fully immersed in the effluent the motor was switched on. The CSTR was thus allowed to attain steady state. pH value of the untreated effluent was recorded and neutralizing agent was allowed to enter the reactor. If the effluent was acidic 0.1 N sodium hydroxide was used to neutralize the effluent, 0.1 N hydrochloric acid was used as neutralizing agent if the effluent was basic. A single tube was inserted through the top cover of the CSTR. The function of this tube was to blow compressed air into the CSTR and thus aerate the effluent present inside. This we hoped would reduce the COD value. The outlet valve of the CSTR was opened and pH of the effluent at outlet was noted.

If the pH was found to be in the range of 6-8 the neutralized effluent was allowed to flow via a distributed network of tubes into the sand bed. Effluent flowing out from the sand bed was collected in a catchment vessel and pumped by a submersible pump to the filtration cum aeration unit.

The effluent was allowed to enter the clearance between the filter wall and it's casing and due to the pressure thus developed because of the confined volume the effluent passed through the filter wall and emerged from the central annular space.

The effluent then passed into the aeration zone where it was broken up into miniature droplets due to the rotational motion of the 4 bladed stirrer. The miniature drops were aerated by compressed air flowing into the aeration zone through small tubes. The effluent emerging from the bottom of the filtration cum aeration unit was collected for further analysis of its TSS and COD value. The TSS value was found by filtering 1 liter effluent though a whatman type glass microfiber filter and drying the filter media at around 103^0C till constant weight was attained. This initial weight of the filter paper was subtracted from the attained constant weight and this gave the value of TSS present in 1 liter of the effluent[10].

For the measurement of COD, the effluent containing known amount of potassium dichromate with known normality was kept at 150^0C on a COD digestion apparatus (spectralab-2015 M) for 2 hours. The blank containing distilled water instead of effluent in the sample tube is also kept at same temperature and for same duration. Silver sulfate and mercuric sulfate are used to fasten the process of decomposition. After two hours the samples were cooled and titrated with Mohrs salt (Ferrous ammonium sulfate) of known concentration using ferroin indicator. The difference in the burette reading for blank and the sample is indicator of the difference in potassium dichromate concentration. The COD is estimated by calculating the equivalent concentration of organic matter required for the consumption of potassium dichromate[11].Multiple experimental runs with various types of effluent having different pH, TSS and COD values were performed and the relevant data recorded.

IV. RESULTS AND DISCUSSION

A. pH control effectiveness.

Fig 1 presents the measured inlet and outlet pH versus the experimental run at which the specific value was obtained. pH control effectiveness of the unit was studied by varying the inlet pH values of effluent in the acidic range i.e. from pH 3-6.5. The effluent was neutralized with 0.1 N solution of sodium hydroxide by keeping the inlet flow rate of the effluent constant but varying the inlet flow rate of the neutralizing agent, in this case sodium hydroxide. pH of the effluent emerging from the end of the filter cum aeration unit was measured and if necessary the flow rate of the neutralizing agent was manually adjusted to obtain neutral pH (7- 8) at the outlet of the unit.

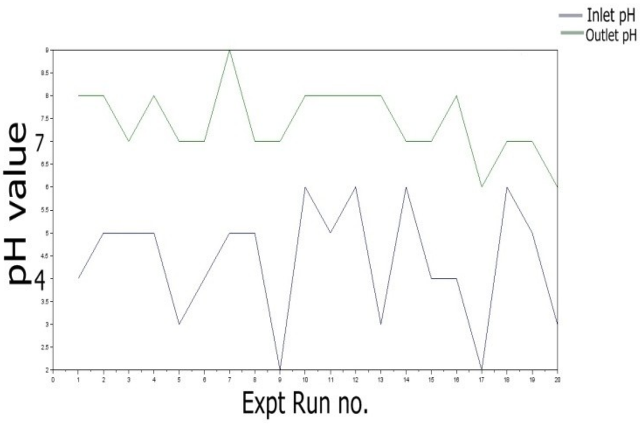

Fig 1:- pH Neutralization effectivenss

B. TSS reduction effectiveness.

Fig 2 presents the TSS values in parts per million (PPM) at the inlet and the outlet of the apparatus for various experimental runs. Effluents having TSS concentration in the range between 500 PPM to 6000 PPM was fed into the apparatus. The suspended solids present in the effluent were then removed due to the filtering action of the multilayered sand bed and drastic reduction of the TSS was seen after passing it through the filtration cum aeration unit. In many experimental runs completely clear effluent was obtained at the outlet of the filtration cum aeration unit. During the experimental runs of a time duration of one hour during which effluent was continuously processed the TSS concentration of effluent obtained at the outlet of the apparatus did not appreciably increase. On an average greater than 90 % reduction in the value of TSS concentration was observed. TSS concentration in the outlet did not exceed more than 100 PPM in any of the experimental runs. In many cases the TSS value was found to be below detectable limits (BDL).

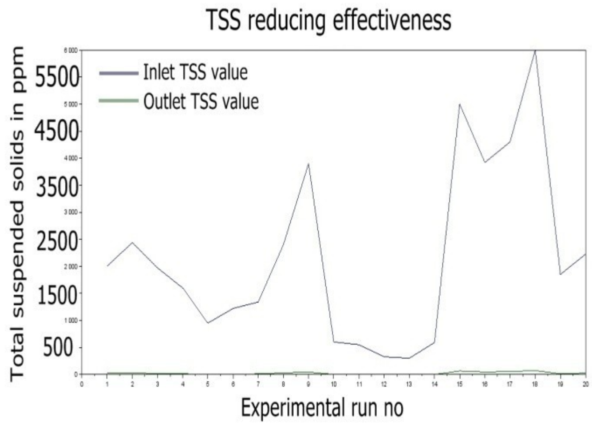

Fig 2:- Variation of TSS values (in PPM) at the inlet and outlet.

C. COD reduction effectiveness.

Fig 3 presents the chemical oxygen demand (COD) values in milligram per liter (mg/l) at the inlet and outlet of the apparatus for various experimental runs. Effluents having COD values in the range of 600 to 1700 mg/l were fed into the apparatus. Aeration was initially carried out inside the CSTR and then the COD values were further reduced due to forced aeration inside the aeration chamber of the filter unit. The steady stream of effluent emerging from the filtration chamber was split up into miniature droplets by the side entering motor driven stirrer inside the aeration chamber, simultaneously compressed air was also blown into the chamber. The large surface area available due to the presence of droplets helped in quick aeration of the effluent. On an average 43 % reduction in COD values was observed at the outlet of the apparatus. The peak COD removal was about 75 % for an effluent from a dye industry and the minimum COD removal was 39 % for a pharmaceutical industry's effluent.

ISSN: 2278 – 7798

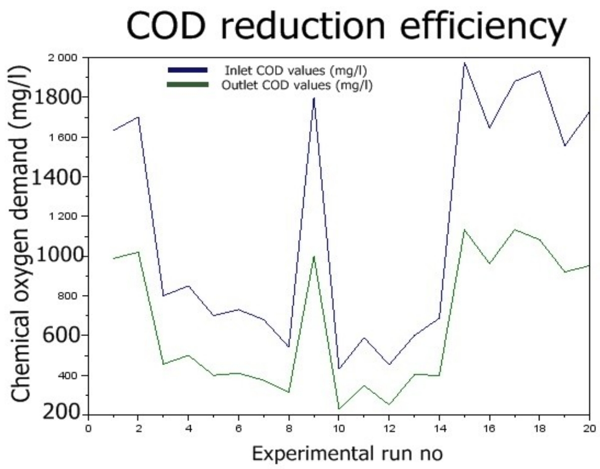

Fig 3 :- Variation in COD values (mg/l) at inlet and outlet

V. CONCLUSION

The apparatus thus fabricated by us was found to be very effective in the control of the critical parameters of the effluent like pH, TSS and COD. Excellent efficiency was obtained for TSS reduction. pH control of the unit was also very effective and neutral effluent was obtained at the outlet. COD reduction was in excess of 40 % over that of the inlet effluent and it must be borne in mind that these results were obtained during a continuous flow of effluent through the apparatus.

- The apparatus was successfully operated in a continuous flow manner for extended durations of time. This is a marked improvement over the current batch type operations practiced in the effluent treatment industry and it was demonstrated that effluents can be treated in a continuous flow type manner.
- Effective pH control for a large range of pH values of the inlet effluent was observed and in all the experimental runs pH obtained at the outlet was neutral. Although for experimentation purposes, the effluents used were predominantly acidic, the apparatus can be easily adapted to treat basic effluents as well by simply changing the neutralizing agent.
- TSS removal efficiency of the apparatus was extremely high and in many cases the TSS values at the outlet were below detectable limits. These low TSS values could be attributed to the removal of suspended particles in the sand bed initially and then the removal of finer particles in the filtration unit. Irrespective of the initial inlet TSS value of the effluent, the outlet value of the TSS was always below 100 PPM.
- COD reduction observed in the apparatus was also fairly good with a peak reduction of 75 % in COD value and an average reduction of around 40 % in the COD values. Irrespective of the inlet COD values of the effluent ,COD reduction was around 40 % leading us to conclude that COD reduction was dependent on the design of the apparatus rather than the inlet COD load. By making design changes in the apparatus COD reduction can be further increased.
- The apparatus was designed and fabricated in such a way so as to enable backwashing. Any valuable chemical present in the effluent can thus be recovered from the filtration unit by backwashing.

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ISSN: 2278 – 7798

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