CHAPTER 8

SUMMARY AND CONCLUSION

Pollution of water is a serious threat to public health and the situation calls for the development of cost effective and environmentally friendly technologies to ameliorate this problem. Skim serum effluent generated in latex centrifuging units is heavily polluted, requiring mandatory treatment so as to reduce the impact of pollution in land and water. This is more important in the context of high density of population and closely-knit dwellings in the state of Kerala. The water bodies which were once the life lines of human habitation have turned out to be the breeding grounds of disease causing microorganisms. Notwithstanding all kinds of pollution control measures imposed by the government and local bodies, untreated or partially treated effluents are discharged indiscriminately to the these water bodies. Consequently the water has turned out to be unfit for aquatic life and human needs.

The overall objective of the present work is to study the effectiveness of certain physico-chemical, electrochemical, biological and radiation methods for the treatment of the highly polluted acidic skim serum effluent on a laboratory scale and thus to develop a systematic treatment system. The treatment methods evaluated in this study had been effective proved to be effective for sewage and effluents from industries like pulp and paper mills, slaughterhouses, pharmaceutical units, citric acid units, distilleries, tanneries, textiles, dye industry and sugar industry.

It is necessary to know the composition of rubber latex to develop a treatment system and its processing. Therefore, a comprehensive
description about natural rubber, composition of rubber latex, different methods of processing natural rubber latex and possible sources of effluent generation are given in the first chapter. The various physical, chemical and biological properties of the wastewater are discussed. The characteristics of effluent from natural rubber processing units, impact of effluent discharge on water bodies and the existing treatment practices are also discussed in brief. The objectives and scope of the work are also defined in this chapter.

In Chapter 2, the characteristics of skim serum effluent from latex centrifuging units are described. The average pH of the serum effluent is 4.11, indicating its acidic nature. COD and BOD of the serum effluent were estimated and the average values were 31603 mg/L and 16756 mg/L respectively. The average ratio between BOD/COD is 0.516 which indicates that the major pollutant is organic in nature. 95.5 per cent of the total solids is in the dissolved form indicating high concentration of organic matter. The major fraction of total suspended solids could be considered as organic matter, since 95.3 % of it is volatile in nature. The presence of total Kjeldahl nitrogen, ammoniacal nitrogen, phosphates, volatile fatty acids, sulphates, sulphide, oil and grease, turbidity and chlorides was also estimated. Concentration of metals as well as biochemical and bacteriological properties were estimated. Most of the characteristics studied are above the limits specified by the Kerala State Pollution Control Board. Therefore, it needs proper treatment before discharging.

Part A of the third chapter comprises the results of a comparative study of five commonly used metal coagulants to remove various pollutants from the serum effluent. The coagulants used were potash alum, ferric alum, aluminium sulphate, aluminium chloride and ferrous sulphates. The effectiveness of metal coagulants was evaluated in terms of the reduction of
turbidity, COD, BOD, TKN, AN and phosphate. The effect of pH on coagulation was also investigated. The optimum pH value for potash alum, aluminium sulphate and ferrous sulphate is 9. For ferric alum and aluminium chloride the optimum pH is 7. Among the five coagulants studied, COD removal efficiency was above thirty percent for all coagulants except ferric alum. Sludge settling characteristics of potash alum and ferric alum were found to be moderate, whereas with ferrous sulphate, floc formation was rapid and settling rate was also fast. Settling of sludge became almost constant within 20 minutes. For aluminium chloride and aluminium sulphate sludge height was quite high showing low compressibility of the sludge.

Effectiveness of three natural polyelectrolytes viz: dried gooseberry powder, dried drum stick seed powder and tamarind seed powder and two synthetic polyelectrolytes (cationic and anionic) as coagulant and coagulant aid to treat skim serum effluent is described in Part B of the third chapter. The optimum pH value for the effective coagulation was 10 for all the polyelectrolytes. The natural polyelectrolytes show high potential as coagulant aid in the treatment process. Tamarind seed powder was found to be the most effective primary coagulant and coagulant aid among the five polyelectrolytes. A small quantity of polyelectrolyte, 4 mg/L, along with a very small amount of metal coagulant could reduce COD and phosphate considerably. When polyelectrolytes in conjunction with metal coagulants were studied, potash alum was found to be the most effective among the metal coagulants in all cases except cationic polyelectrolyte. In the case of cationic polyelectrolyte, aluminium chloride was more effective. Among the synthetic polyelectrolytes, cationic polyelectrolyte was more effective than anionic polyelectrolyte.
The topic of discussion in Part A of the fourth chapter is the treatment of skim serum effluent by UASB reactor. Performance of the reactor was evaluated in terms of the variations in pH, COD, BOD, sulphide, volatile fatty acids, total Kjeldahl nitrogen, ammoniacal nitrogen, total solids, dissolved solids, phosphate and volatile suspended solids. The volume of biogas produced was measured by the downward displacement of water. The studies revealed that UASB reactor could be successfully used to treat skim serum effluent. For an HRT of 36 days, average COD removal efficiency was 89 and 79 percent at an organic loading of 27 and 37 kg/day/m$^3$ respectively. Decreasing HRT and increasing organic loading decreased the efficiency of the treatment. The reactor height influenced the treatment efficiency and the percentage removal of COD increased as the effluent moves upwards and the maximum percentage removal was at the top of the reactor. Efficiency of treatment could not be assessed in terms of BOD since BOD values were unusually high during anaerobic treatment for longer HRTs. pH and VFA changes are more pronounced below 1.3 metre height, indicating high rate of anaerobic reactions at the lower part of the reactor. Lowering HRT from 36 days to 9 days decreased the efficiency of removing total solids and dissolved solids, whereas increasing organic loading increased the percentage removal of TS and DS showing the need for longer periods of retention for the removal of solids. Major portion of the TS and DS was removed below 1.3 meter height proving substantial settling of the sludge below this height.

High amount of VSS is formed at the lower part of the reactor. This could be a sign of high biomass formation at the lower part of the reactor. Total Kjeldahl nitrogen and ammoniacal nitrogen removal were rather low compared to COD. Percentage removal of ammoniacal nitrogen shows wide
variation ranging from negative to zero. For higher HRTs, 97 percent removal of soluble organic nitrogen content was achieved during anaerobic treatment. High percentage removal of soluble organic nitrogen indicated the degradation of nitrogen containing compounds like proteins and amino acids during anaerobic treatment. Biological phosphorus removal was higher for longer retention times in the UASB reactor and *vice versa*. Large amount of sulphide was formed during this process of treatment but its presence did not seriously affect the treatment efficiency since 85 to 95% COD was removed. The biogas produced was measured and its quantity decreased when HRT decreased. Anaerobic process removed the concentration of heavy metals like iron, copper and zinc. Biochemical studies of the serum effluent showed that anaerobic treatment by UASB reactor is an effective method to remove protein, sugar and even phenol.

Part B of the fourth chapter explains the investigations into the effect of trace metals like Co, Ni and Mo individually and in combination at 100 and 10 µg/L concentrations on the anaerobic treatment of skim serum effluent using batch type upflow anaerobic sludge blanket in comparison with another set without any added metal. Average sulphide formation was higher when metal concentration was 10 µg/L than at 100 µg/L. But, formation of sulphide was comparatively low in the presence of Ni and Mo. Turbidity in the presence of cobalt was comparatively high, showing that the presence of cobalt favoured cell growth than any other metal. But for 10 µg/L concentration of trace metals Mo containing effluent had high value of turbidity. Measurement of turbidity could be used to assess the cell growth. Continuous addition of 100 µg/L of Co increased the percentage removal of COD to an optimum value and then declined. Continuous addition of Ni and all the three metals
together caused an abrupt decline in the percentage removal of COD, showing the inhibitory effect of metals. In the removal of COD, influence of Mo was higher than Co when 10 µg/L of trace metal was added indicating the need for traces of Mo in the anaerobic treatment. Increase in BOD values during anaerobic treatment in the presence of trace metals indicated a constant interference in the measurement of BOD. Trace metals did not influence much in the removal of total Kjeldahl nitrogen and ammoniacal nitrogen. Percentage removal of ammoniacal nitrogen was negative, which confirmed the formation of ammonia during anaerobic treatment.

Chapter 5 discusses the effect of anodic oxidation of raw and anaerobically treated skim serum effluent. Electrochemical method could be used for pre-treatment as well as post-treatment of this effluent. But post-treatment was more effective. Sodium chloride was used as supporting electrolyte. Various metal electrodes like aluminium, cast iron, steel, and mild steel were compared for their efficiency in removing COD, BOD, TKN, AN and phosphate and found that aluminium anode was more effective to remove pollutants compared to others. Also studied the effect of Fenton’s reagent in electrolysis and found that the presence of Fenton’s reagent during electrolysis was very effective in removing pollutants. Maximum removal of COD took place within 45 minutes and BOD within 30 minutes. Therefore, 45 minutes could be taken as the optimum time for electrolysis. Instantaneous current efficiency decreased with time during electrolysis and finally reached a constant value after 120 minutes. Effect of concentration of effluent on electrolysis showed that the lower the COD of the effluent used for electrolysis, the higher the rate of removal and it was more prominent in the case of the anaerobically treated effluent. 99.5
percent phosphate could be removed from the anaerobically treated effluent by electrolysis. Electrolysis was more effective for the treatment of anaerobically treated effluent having low organic load. Complete removal of sulphide was observed during electrolysis. pH around 5 could be taken as optimum for electrolysis in the presence of Fenton’s reagent since maximum percentage removal of COD and BOD took place at pH 5. With the help of a photovoltaic cell, solar radiation was used to treat these effluents and compared its efficiency with DC power and found that solar cell was very effective as an alternative source of power to treat serum effluent by electrochemical method. The use of photovoltaic cell is highly efficient and economical once it is installed. Biochemical analysis revealed that electrolysis in the presence of Fenton’s reagent was good in removing soluble protein, phenol and sugars especially from the anaerobically treated effluent. Sugar and soluble proteins were completely removed by electrolysis. Microbiological analysis showed that population of total bacteria could be completely removed by 20 minute electrolysis in the presence of Fenton’s reagent. It is concluded that anodic oxidation is one of the best methods for the treatment of anaerobically pre-treated effluent.

Chapter 6 discusses the feasibility and efficiency of different adsorbents and the selection of the best adsorbent to purify anaerobically and electrolytically pre-treated skim serum effluent. Different forms of activated carbon, carbon black and nano clays were used to purify the pre-treated natural serum effluent. This study showed that commercially available activated carbon and furnace carbon black were good adsorbents to purify this effluent. Activated carbons prepared from coconut shell, rice husk, saw dust and teak wood saw dust were also used as adsorbents, since these different natural substances are cheap and easily available in Kerala.
Out of these, activated carbon prepared from coconut shell was the best adsorbent for the removal of COD. The order of their efficiency in terms of COD and BOD removal is coconut shell > rice husk > teak wood saw dust > saw dust. Nano clays were good to remove COD, total nitrogen and ammoniacal nitrogen. Though nano clays were good adsorbents, further studies need be carried out to evaluate the biochemical as well as economical aspects.

Chapter 7 explains the impact of gamma irradiation from a Co-60 gamma source in the presence of Fenton’s reagent on the treatment of raw and anaerobically treated skim serum effluent in terms of effective organic contaminant decomposition as indicated by the measurements of COD, BOD, total Kjeldahl nitrogen, ammoniacal nitrogen, total solids and dissolved solids. The impact of these factors on the biochemical constituents like soluble protein, free amino acids, phenol, total sugar, reducing and non-reducing sugars and population of total bacteria was also studied. Maximum removal of pollutants was observed at 2.5 to 3 kGy, when raw effluent was irradiated for a dose range of 0.5 kGy to 100 kGy. Effect of irradiation was more prominent in the presence of Fenton’s reagent. Gamma radiation in the presence of Fenton’s reagent was more effective on anaerobically treated effluent. pH around 7 was good to treat raw effluent using gamma radiation but pH around 3 was effective for gamma irradiation in the presence of Fenton’s reagent. Sulphides present in the anaerobically treated effluent could be completely removed when irradiated in the presence of Fenton’s reagent. Biochemical analysis of the raw effluent after irradiation in presence of Fenton’s reagent showed that a dose of 2.5 kGy could remove appreciable amount of soluble protein, phenol and free amino acids. But the effect was more pronounced when
anaerobically treated effluent was subjected to gamma radiation for the same radiation dose of 2.5 kGy. Complete removal of total sugar as well as reducing and non reducing sugar was possible when anaerobically treated effluent was subjected to irradiation in the presence of Fenton’s reagent. Gamma irradiation having a dose of 2.5 kGy in the presence or absence of Fenton’s reagent completely removed total bacterial population of raw effluent whereas in the case of anaerobically treated effluent the dose was in between 5 to 10 kGy.

**Proposed treatment system for skim serum effluent**

The study was undertaken with the objective of evolving a treatment system to mitigate the health hazards of the effluent, with special emphasis on the effluent discharged from the rubber processing units which are aplenty in the rubber growing belts of central Kerala, particularly Kottayam district.

Based on the studies undertaken and the observations made, the treatment system evolved in a laboratory scale is outlined below.

pH of the serum effluent collected from latex centrifuging unit was in the range of 3.6 to 4.7. This is raised to increase the pH to 8.5 to 9 by the addition of sodium hydroxide and lime. Sodium hydroxide was used along with lime to minimise the quantity of sludge formation. After adjusting the pH, potash alum was used as a coagulant to settle colloidal and suspended particles. Coagulation removed a part of the pollution load as evidenced by the decrease in the values of COD and BOD. Very low concentration of tamarind seed powder could also be added along with metal coagulant to enhance the coagulation process. COD of the raw effluent was in the rage of 27000 to 38800 and BOD was 10500 to 23280 mg/L respectively and by
coagulation these parameters were reduced to 19000 to 27000 and 7350 to 15000 mg/L respectively. The clear solution after coagulation was filtered and fed into the UASB reactor for anaerobic treatment, where the organic pollutants were removed biologically. Microgram quantities of cobalt (100 µg/L) and molybdenum (10 µg/L) enhanced the treatment efficiency of the UASB reactor. Anaerobic treatment was essential for skim serum effluent due to its high pollution load. In the UASB reactor the effluent without dilution was used. Therefore, an HRT of 18 days was essential for proper treatment, especially for higher organic loadings. The main advantage of UASB reactor was the simplicity in design, ability to retain high biomass that lead to the efficient removal of organics at high loading rates and low energy demands. Only minimum power supply was needed and the whole plant could be kept operational at all times. COD of the effluent from the UASB reactor was in the range of 3595 to 4508. Most of the biochemical constituents including phenol were reduced. One of the disadvantages of the anaerobic treatment process was the formation of sulphide, since the effluent contained high concentration of sulphate.

The effluent from the UASB reactor was then subjected to electrochemical treatment in the presence of Fenton’s reagent. Photovoltaic cell could be used as the source of power (DC power could also be conveniently used). Cost of treatment could be minimised since the source of power in photovoltaic cells is solar radiation. Electrochemical treatment in the presence of Fenton’s reagent was an excellent method for the post-treatment of anaerobically treated effluent since it completely removed the sulphides from the anaerobic process. The COD of the effluent after electrochemical treatment was in between 816 to 1499 and BOD was 290
to 464. Biochemical constituents like soluble proteins and soluble sugars were completely removed by the electrochemical treatment.

Gamma radiation was effective to treat the anaerobically treated effluent in the presence of Fenton’s reagent since it removed high percentage of COD, BOD and sulphides and inactivated pathogenic microorganisms from the effluent. But the non-availability of the radiation source limits its use as a common method of treatment. Electrochemical treatment can be replaced by gamma radiation treatment, if the radiation facility is not available.

UASB and electrochemical treatment when combined together removed the major part of the pollutants from the serum effluent. The disadvantages of the UASB were compensated by electrochemical treatment. The presence of electrons during electrochemical treatment electrocute microorganism in the biologically treated water and the microbial population present in the anaerobically treated effluent was completely removed by this method.

The effluent after electrochemical treatment was further purified by adsorption on activated carbon. This process gave a very clear solution and removed substantially the remaining pollutants, except TKN and AN for which further treatment was needed. The COD of the purified effluent was 122 to 240 and BOD was 9 to 14. These values were well below the standards prescribed by the Kerala State Pollution Control Board. A flow chart of the treatment system is given below.
It has been finally concluded that the pollutant load of serum effluent can be brought down to below the tolerable levels-standards prescribed by the Pollution Control Board - through the following sequence of processes (i) coagulation of the serum effluent, (ii) anaerobic treatment using UASB reactor, (iii) electrochemical oxidation or gamma radiation process and (iv) adsorption on activated carbon.

**Fig. 8.1.** Flow chart of the suggested treatment system