CHAPTER FOUR : RESULTS AND DISCUSSION

4.1 Characteristics of Rubber Glove Manufacturing Industry Wastewater.

The raw effluent from all three factories, A, B and C exhibited similar characteristics particularly in the six main parameters i.e. BOD, COD, suspended solids (SS), oil and grease, zinc and pH. Table 4.1 shows the characteristics of the raw effluent from the samples collected periodically throughout the three months for Factory B and C and four months for Factory A. The ranges of values for each of the parameters observed are listed in Table 4.1.

Table 4.1 : Characteristics of Effluent from Rubber Glove Manufacturing Factories

Parameter	Factory A	Factory B	Factory C
pH	5.1-8.4	5.8-7.3	5.9-7.0
BOD	85-600	204-1035	90-161
COD	300-1490	523-4360	80-500
Suspended Solids (SS)	184-1305	32-1244	50-521
Oil & Grease (O & G)	16-114	6-107	9-45
Zinc (Zn)	0.48-11.6	0.48-82	2.1-50.6

All parameters except pH are expressed in mg/l or ppm.

As shown in Figure 1.1, there were four types of effluent, identified as Effluent A, B, C and D and these were discharged during the entire glove manufacturing process.

Effluent A was generated during the cleaning of rubber glove formers, while the source of effluent B was the latex dipping process. In this process, the formers were immersed into the latex compound for a predetermined followed by a slow withdrawal of the formers to ensure a smooth and uniform thickness of deposit is obtained. As this process required a high and constant temperature, water was used to cool off the tank. The used water, which was high in temperature, was discharged as effluent.

The second type of effluent found in effluent B was the sludge from the latex dipping tank itself. The sludge was formed from the sediments or residuals in the latex compound or the coagulants. Effluent C was the main source of effluent for rubber glove manufacturing. It was generated from the leaching tank. Leaching process involved the removal of water-soluble materials or residues such as coagulant, soaps and serum using hot water. These materials contained high concentration of pollutants and subsequently contributed to the high BOD, COD and SS content in the effluent.

The latex compounding step involved the transformation of latex concentrate into a range of materials suitable for different types of applications, by adding additives into the latex concentrate. There are three classes of additives namely, stabilisers which help to ensure adequate processing stability; vulcanising agents to effect the x-linking of the rubber and lastly protective agent which ensure adequate service life. Other chemicals that may be required depending on the nature of the process or on end-use are gelling agents, thickeners, pigments, fillers and tackifiers. The washing of tanks and other equipment used during the compounding process and also spillage or residual of the chemicals used eventually contribute to high BOD and COD levels in the discharged effluent, identified as Effluent D in Figure 1.1.

All these four types of effluent, identified as Effluent A, B, C, and D would be equalised in the equalisation basin prior to primary treatment. The objective of the equalisation basin is to minimise or control the fluctuations in the wastewater characteristics in order to provide constant conditions for subsequent treatment processes.

Except for effluent from Factory A, which pH value ranged from 5.1 to 8.4 i.e. from acidic to alkaline, effluent from Factory B and C shown the characteristic of from acidic to neutral. Their pH values ranged from 5.8 to 7.3 and 5.9 to 7.0 respectively. Similar pH value ranging from 6.83 to 7.72 was recorded in five other glove factories as reported by Zaid, (1988) (see Table 2.6) and Nambiar *et. al.*, (2000). With this pH condition, the neutralisation step immediately after equalisation basin was no longer critical. It is extremely important to neutralise raw effluent that may contain acidic or alkaline materials that may become an obstruction or affect the chemical-physical treatment and more so the biological treatment.

However, the raw effluent contained fairly high concentrations of BOD and COD, with BOD concentration ranging from 85 ppm to 1035 ppm among these factories. Due to the different chemicals used for different stages in the manufacturing processes, these effluents contained different concentration of pollutants. When these effluents were discharged at various stages and at different discharging pattern, it resulted in a wide range of BOD and COD concentrations as found in the analyses. Zaid and

Nordin (1991b) reported similar BOD concentration with a range from 79 to 435 in the raw effluent of glove manufacturing factories.

A nation-wide survey on the latex-based industries was carried out by the Technical Committee for the rubber based industry waste in 1999 (Zaid, 2001). A total of 60 rubber product manufacturing factories were selected for the survey. Rubber gloves manufacturing factories constituted 63%, followed by latex thread (8%), condom (5%), mixed products (10%) and the remaining 7% are the foam products, rubber line, toy balloon and finger cot manufacturing factories (see Table 2.5). From the survey, it was found that raw effluent from rubber glove manufacturing industries contained BOD concentration at the range of 20 to 2170 mg/l with the mean value of 276 mg/l.

COD concentration in the raw effluent collected from Factory A, B and C were observed to vary from 300 to 1490 mg/l for Factory A, 523 to 4360 mg/l for Factory B, and lastly from 80 to 500 mg/l for Factory C. These COD concentrations fell within the range of 98 to 3058 mg/l observed from the survey on the latex-based industries (Zaid, 2001). Similarly, the raw effluent discharged from five examination glove factories contain COD concentration ranging from 117 to 1237 mg/l, as reported by Zaid (1997). Subbiah and Alui (1999) also reported similar range of COD concentrations i.e. from 208 to 1210 mg/l in a case study of a latex glove factory. Examination gloves industry effluent gave COD level of 2011, while household gloves industry wastewater contained 2250 mg/l of COD (Sastry, 1995). Generally it was found that the BOD concentrations were significantly lower than the COD concentrations, and the ratio of BOD to COD in the rubber glove manufacturing factories varied from 0.4 to 0.6. Thus, biological processes can treat this kind of wastewater.

The similarity in BOD and COD concentrations found in this study, as well as studies by Zaid (1988 and 1990b) and the nation-wide survey results based on the 38 rubber glove manufacturing factories proved that the characteristics for this type of effluent were quite consistent. This would make the treatment of this type of wastewater easier.

Among the many latex-based products such as rubber gloves, catheters, latex thread, condoms and foam products, effluent from latex thread industry contained higher or comparable concentration of pollutants to the rubber gloves effluent. The COD and BOD concentrations from three rubber thread manufacturing factories varied from 4690 to 6562 mg/l and from 3993 to 5793 mg/l respectively (Subbiah, 1997). Meanwhile, effluent from condom manufacturing factories has a much lower BOD and COD concentrations, with a mean value of 109 mg/l and 311 mg/l, respectively. Effluent from catheter manufacturing factories was much easier to treat as it has a mean BOD value of 64 mg/l and mean COD value of 211 mg/l (Zaid, 2001).

Another important parameter included in this study is the suspended solids (SS) concentration in the effluent. The concentration of SS detected from the effluent varied from 32 to 1305 mg/l (see Table 4.1), as compared with 7 to 2413 mg/l (Zaid, 2001). However, the SS content identified in the effluent from examination glove manufacturing industries was only 241 mg/l and household gloves 148 mg/l (Zaid, 1991a). Unlike BOD and COD, effluent from rubber thread manufacturing factories contained lower SS concentration. It was found that the SS concentration varied from 256 to 473 mg/l in its effluent (Subbiah *et. al*, 2000 and Agamuthu, 1999). While the total solids in the latex concentrate and SMR effluent are much higher with a concentration of 7576 mg/l and 1915 mg/l, respectively, the SS in the effluents was rather low i.e. 182 mg/l and 237 mg/l (Zaid 1993b). The main sources of wastewater from SMR manufacture include bulking, acid coagulation and milling, as compared to rubber glove manufacture where its effluent come from former cleaning, latex dipping, leaching and latex compounding steps. For instance, the latex compounding waste contains uncoagulated latex and chemical sludge. The involvement of different manufacturing processes resulted the differences in the SS concentration of the effluents.

Three main parameters i.e. BOD, COD and SS were selected in this study, whereas parameters such as Zinc, Oil & Grease, pH and others were analysed for the raw effluent only and not for the intermediate and treated effluent since the former posed critical and main obstacles in the effluent treatments, as compared to other parameters.

4.2 Treatment of Effluent

4.2.1 General

While the size of the wastewater treatment plants (WWTPs) for Factory A, B and C are different, the basic design systems adopted for these treatment plants are alike.

The treatment systems generally involved the initial equalisation step, followed by chemical-flocculation and physical separation with DAF as the primary treatment, the activated sludge process (extended aeration system) as the biological treatment, and lastly the sludge thickening and disposal system, as shown in Figure 4.1.

4.2.2 Pre-treatment and Equalisation

All the three factories have either a rubber trap or a coarse screening system installed at the up front of the effluent treatment plant prior to the equalisation basin. The main purpose of this screening system is to separate out the latex coagulates or crumbs from going into the WWTP. Besides recovering the latex coagulate which could be recycled for use, it is extremely critical to remove these coagulates to avoid any damage to the equipment of the WWTP such as pumps, valves, pipelines and other equipment. For example, the impeller of the transfer pumps can easily be damaged if the latex is caught at the impeller or clogging of pipelines or even valves that could not be closed or opened as required due to the deposits of latex coagulates at the valve disc or body. Thus, screening is considered a pre-treatment step prior to the actual treatment of the raw effluent (see Figure 4.1).

The WWTP starts with the influent of wastewater into the equalisation basin. The variation of effluent flow rate, its characteristics and strength due to the manufacturing process will be equalised in the equalisation basin. The main objective of the equalisation basin is to minimise or control the fluctuations in wastewater characteristics in order to provide optimum conditions for subsequent treatments

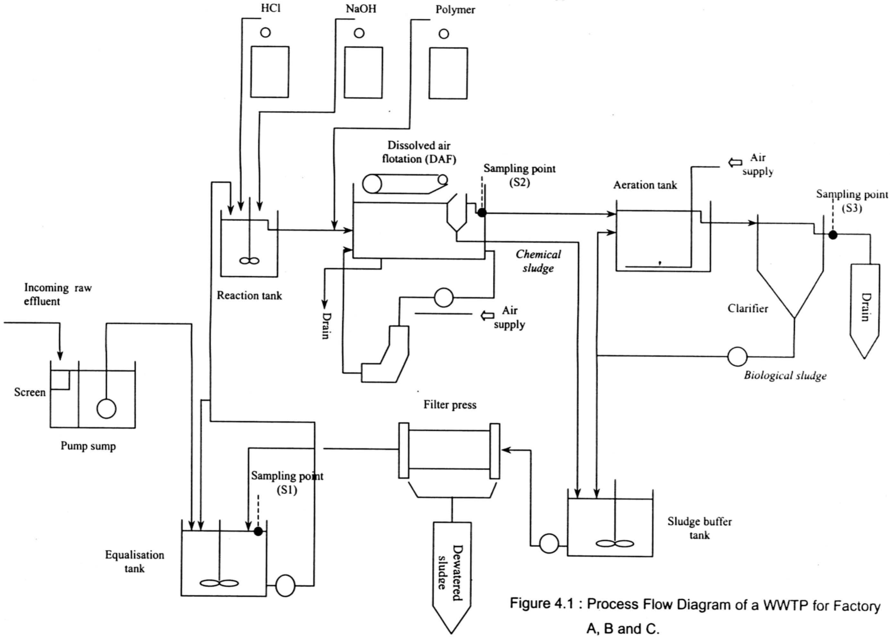

Figure 4.1 : Process Flow Diagram of a WWTP for Factory A, B and C.

(Vacker, 1997). High short-term loading such as the discharging of large amount of wash water generated from the washing of leaching tank and latex-dipping tank periodically would create situations of 'shock loading' to the treatment plant. The equalisation tank helps to create an equalised flow rate and thus overcome the operational problems caused by flow rate variation. Furthermore, it improves the performance of the downstream processes, and reduced the size and cost of downstream treatment facilities. The apparent benefits from the equalisation process are as follows (Metcalf and Eddy, 1991):

1. The equalisation basin acts as a buffer zone, and subsequently reduces or minimises the 'shock loading'. Besides, the presence of inhibiting substances in the effluent and toxic materials can be diluted and pH can be stabilised. All these will enhance the biological treatment down stream.
2. The constant solid loading also enhances the effluent quality and thickening performance of secondary sedimentation tank.
3. In the succeeding chemical treatment, damping of mass loading improves chemical feed control and process reliability.
4. A continuous feed to biological system over periods when the manufacturing plant is not in operation is ensured.

Either mechanical mixers or diffusers are used to provide the mixing mechanism in the equalisation basin. The mixing ensured adequate equalisation and also to prevent setteable solids from depositing at the bottom of the basin. In order to maintain a constant flow rate from the equalisation basin onwards, pumps are normally used to transfer the effluent to the reaction tanks (Figure 4.1).

4.2.3 Chemical Treatment

Effluent from equalisation basin is pumped to the reaction tanks, where chemicals are dosed into the effluent. Often the chemical treatment involves 2-step treatment or also known as stepwise addition of chemicals. In the first step, pH of the raw effluent was adjusted to approximately 11 with lime or caustic soda (NaOH) before it is flocculated with flocculants such as lime or polyelectrolyte. The flocculation process removes all metallic elements such as zinc and other residual toxic chemicals in the effluent, by combining the colloidal particles of heavy metals such as zinc into larger agglomerates and subsequently removed by settling. Alum or polymer was dosed in at the second step to enhance the coagulation process by promoting the growth of large, rapid-settling flocs. Similar chemical treatment method was applied in a prototype effluent treatment system for RRIM rubber glove manufacturing plant (Zaid, 1997). Ooi (1993) used alum and polyelectrolyte separately in his study on zinc removal from rubber thread manufacturing industries effluent.

The chemical flocculation-coagulation treatment is important as it eliminates the toxic and hazardous elements in the effluent prior to biological treatment. If these toxic elements are not removed up front, the growth of the microorganisms in the following biological treatment and its biological activity will be affected.

4.2.4 Primary Sedimentation

All three factories A, B and C adopted the dissolved-air flotation (DAF) system as the primary sedimentation step, instead of the conventional clarifiers. While the function of both systems was similar, however the removal efficiency particularly SS, BOD and COD by DAF system was found to be higher as compared to the conventional clarifiers. It was observed that this system enabled a cleaner water phase and a sludge phase that was much thicker than can be achieved using a conventional clarifier. DAF with chemical flocculation system was adopted in an upgrading exercise of a condom manufacturing factory, and was found to achieve consistent reductions of 70%, 60%, 94% and 80% for BOD, COD, SS and Oil and Grease respectively (Meyers, 1995). For comparison, Nordin and Zaid (1997) adopted a conventional clarifier in their prototype effluent treatment system for RRIM rubber glove manufacturing plant. They reported that the clarified effluent exiting the clarifier indicated a 46.6% removal of COD, 78.7% removal of BOD and 65.4% removal of SS.

Latex effluent is not a particularly high strength wastewater compared to other kinds of wastewater such as effluent from slaughterhouse, food processing and cosmetics industry. Even these difficult effluents had been successfully treated using DAF system. Meyers, 1995 reported that the use of DAF system resulted in reduction of 72.3% BOD, 99.6% SS and 96.6% grease in the pet food manufacturing factories; while the silk screen printing industries experienced a reduction of 99.87% BOD, 99.6% SS and 90.3% grease. Similar results were reported in the poultry slaughterhouse industries (Meyers, 1980).

4.2.5 Biological Treatment

Biological treatment of the partially treated effluent in Factory A, B and C involved an extended aeration system. This system was basically an activated sludge process where the clarified water from DAF enters the head-end of the aeration tank. Recycled activated sludge from the secondary clarifier also enters the head end. Either diffused-air or mechanical aeration was used to assist mixing of both of these liquids in the aeration tank. The air application was generally uniform throughout the tank length.

Three main criteria in the design parameters for this type of system were i) food to microorganisms (F/M) ratio, ii) sludge age and iii) mixed liquor suspended solids concentration. Typical values for the F/M ratio reported in the literature varied from 0.05 to 0.15 per day, while sludge age varied from 20 to 30 days (Metcalf and Eddy, 1991). F/M ratio for both Factory A and B was approximately 0.2 per day and 0.1 per day for Factory C. Even though the F/M ratio for Factory A and B was slightly higher than the recommended F/M value of 0.05 to 0.15 per day, it was found that both WWTPs performed well.

4.2.6 Secondary Sedimentation

The performance of the biological system depended on the separation of solids in the secondary sedimentation tank. In fact, the final clarifier was a key element in the activated sludge process. It performed two main functions i.e. i) separation of the mixed liquor suspended solids from the treated wastewater, which resulted in a clarified effluent for discharging; and ii) thickening of the return sludge, which was recycled back to the aeration tank.

The clarified effluent at this stage had undergone two stages of treatments i.e. the primary treatment (clarified effluent from DAF) and the secondary treatment (clarified effluent from clarifier) as shown in Figure 4.1. As such this 'double-stages' clarified effluent, which was also known as treated effluent, was able to meet the regulatory standards of DOE prior to discharging into the rivers or receiving water (see Appendix II).

Meanwhile, a large portion of the sludge settled at the bottom of the clarifier was recycled to the aeration tank as returned activated sludge (RAS) and the balance was treated as waste sludge (WAS). The purpose of recycling the activated sludge back to the aeration tank was to maintain a sufficient concentration of activated sludge in the aeration tank itself. The RAS pumping capacity was 100% of the wastewater flowrate. This was to ensure that the percentage of RAS was at least 75% of the excess sludge, while the remaining 25% as WAS was discharged into the sludge thickening tank in the next stage (Sastry and Thambirajah, 1995). The ratio of RAS and WAS was maintained through the opening of the valves and the size of the pipes to both the aeration tank and sludge buffer tank (see Figure 4.1). WAS is critical so as to maintain a given F/M ratio or mean cell-residence time.

4.2.7 Sludge Thickening and Disposal

Chemical sludge produced from the chemical flocculation stage and was drawn from the DAF unit into a sludge buffer tank. Similarly WAS from the biological stage is drawn from the secondary clarifier into the sludge buffer tank (Figure 4.1). The chemical sludge was larger in volume compared to the WAS as most of the WAS was recycled back to the aeration tank. The composition and the characteristics for these two types of sludge varied considerably. Solid content in the primary sludge was normally within the range of 2.0 to 8%, however, in WAS the solid content was within the range of 0.83 to 1.16%. By mixing these sludge, the next stage of sludge thickening was much easier.

In the sludge buffer tank, the mixed sludge was thickened with the help of coagulants such as polymer or lime. All three WWTPs used polymer as the coagulant aid since polymer was found to be suitable for these effluent. The thickening or concentration of sludge reduced the sludge volume and eventually reduced the capacity of tanks and equipment in subsequent dewatering process.

Filter press was found to be suitable for latex waste as seen in all three factories A, B and C (see Appendix II). These factories did not encounter any issue of watery sludge solid, but instead have observed high concentration of cake solid and clear filtrate from their filter press units.

As the effluent from the rubber glove manufacturing factories contained heavy metals such as zinc, lead and iron, the sludge cake generated from the dewatering process was considered as scheduled waste according to the regulatory standards of DOE. Such sludge cake was be drummed up in proper containers before disposing of at a scheduled waste landfill.

4.3 Removal of BOD from Rubber Glove Manufacturing Industries Effluent

Detailed analysis was carried out on BOD removal at different stages of the treatment process for Factory A, B and C. Samples were collected at the equalisation basin, outlet of DAF and outlet of the final clarifier. The first sampling point represented the raw effluent that has not undergone any treatment yet. The second sampling point represented effluent undergone the primary treatment comprising chemical flocculation and physical separation, also known as physico-chemical treatment. The third sampling point reflected the treated effluent, where the effluent has been treated in the biological system and undergone the secondary sedimentation prior to discharge into the receiving water.

The concentration of BOD for the raw effluent, after DAF and treated effluent (after aeration tank) were tested and analysed. The actual removal of BOD by chemical flocculation and DAF system and by biological system was measured to determine the removal efficiency for all three factories.

4.3.1 Removal of BOD in Effluent from Factory A

Results of the study on the removal of BOD from rubber glove manufacturing industry wastewater at three stages of treatment i.e. raw effluent, after primary treatment and after secondary treatment are shown in Table 4.2. The monthly average BOD concentration for the raw effluent was found to be ranging from 167.4 to 306 mg/l throughout the 4 months of study. Compared to other types of effluent, rubber glove manufacturing industry effluent can be considered as moderate. BOD concentration in effluent from the two main rubber processing factories, namely latex concentrate and SMR has been reported to be 3192 mg/l and 1747 mg/l respectively (Zaid, 1993). Effluent from rubber thread manufacturing factories has higher concentration of BOD, estimated to be at 7500 mg/l (Subbiah and Alui, 1999 and Agamuthu *et. al.*, 2001)). Other types of agro-industries, which have very high concentration of BOD in the effluent, are tapioca starch factories and palm oil mills. Effluents from these industries were reported to contain BOD concentration ranging from approximately 2600 to 19500 mg/l (Tanticharoen *et.al*, 1991) for the former and 341 to 3920 mg/l for the latter (Phang, 1991).

Data collected has indicated that the treatment plant was functioning satisfactorily. The overall removal of BOD from raw effluent of the rubber glove manufacturing was very significant. The treated effluent, which was after the biological treatment, reported BOD, ranged from 4 to 8 mg/l, giving a removal of more than 96%. The treated effluent was well below the DOE permissible discharge standard A and B of 20 mg/l and 50 mg/l, respectively, and can be safely discharged into receiving water.

Figure 4.2 showed the BOD concentration at different stages throughout the 4-month of sampling period.

Table 4.2 : Monthly Average BOD Concentration at Different Stages of Effluent Treatments for Factory A

Month	BOD of Raw Effluent	BOD After Physical-chemical Treatment	% BOD Removed	BOD of Treated Effluent	% BOD Removed	Overall BOD Removal (%)
1	306 ± 20	77 ± 6	75	7 ± 0.2	91	98
2	167 ± 10	15 ± 2	91	6 ± 0.7	60	96
3	289 ± 25	48 ± 5	83	4 ± 0.3	92	99
4	274 ± 13	76 ± 7	72	8 ± 0.7	90	97

BOD concentrations are expressed in mg/l.

From the observations on BOD removal efficiency at different treatment stages, it was found that both the primary treatment and biological treatment have achieved high efficiency of BOD removal, as shown in Figure 4.3. The primary treatment, which was a physical-chemical treatment removed an average of 80% BOD from the raw effluent. The chemical-flocculation together with the DAF system managed to remove a substantial amount of carbonaceous organic matters from the latex effluent. Except for Month 2, the subsequent biological treatment also reduced approximately 90% of BOD from the effluent.

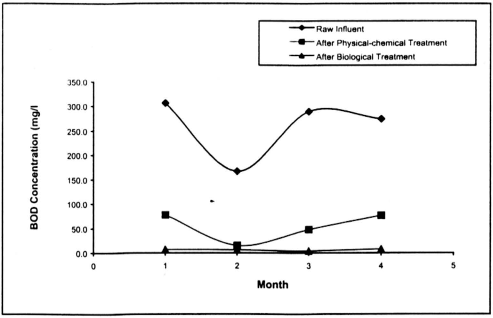

Figure 4.2 : BOD Concentration at Different Stages of Effluent Treatment at Factory A

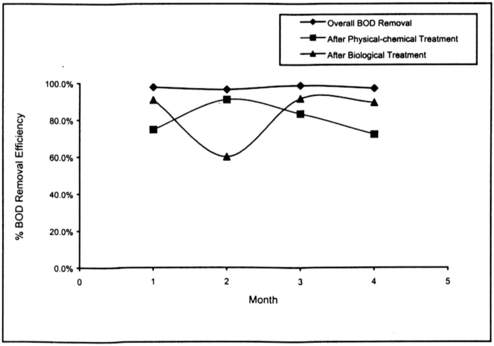

Figure 4.3: Percentage BOD Removal Efficiency at Different Stages of Effluent Treatment at Factory A

4.3.2 Removal of BOD in Effluent from Factory B

Raw effluent collected from Factory B was found to exhibit slightly higher BOD concentration as compared to Factory A. The monthly average concentration of BOD varied from 267 to 450 mg/l, as shown in Table 4.3. Observation showed that the overall removal of BOD was quite good even though the percentage removal was lower compared to Factory A. Generally the removal varied from 87 to 97% with an average of 93% (Figure 4.4). The treated effluent for Month 3 exceeded the limit of regulatory standard A which required for 20 mg/l. However, this result was still acceptable, as Factory B which is located at a downstream area, was only required to adhere to Standard B of DOE's Regulatory Standards with a limit of 50 mg/l.

Table 4.3 : Monthly Average BOD Concentration at Different Stages of Effluent Treatments for Factory B

Month	BOD of Raw Effluent	BOD After Physical-chemical Treatment	% BOD Removed	BOD of Treated Effluent	% BOD Removed	Overall BOD Removal (%)
1	450 ± 32	45 ± 3	90	15 ± 0.1	67	97
2	355 ± 17	78 ± 4	78	19 ±1	76	95
3	267 ± 10	54 ± 2	80	35 ± 3	35	87

BOD concentrations are expressed in mg/l.

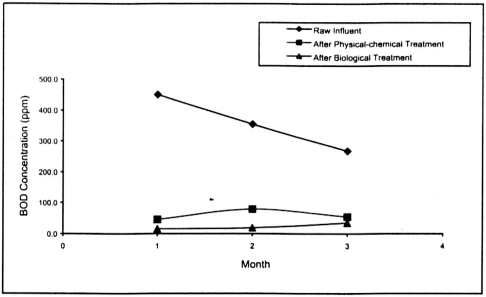

Figure 4.4 : BOD Concentration at Different Stages of Effluent Treatment at Factory B

The study indicated that the primary treatment for Factory B was not as efficient as for Factory A but could still be considered as satisfactory. Its removal efficiency varied between 78% to 90%. For comparison, Zaid (1997) reported removals of 75% by chemical flocculation–conventional clarifier for BOD. From a survey conducted by RRIM on the existing effluent plants, removal of BOD ranged from 26.7% to 43.1% (Nordin and Zaid, 1997).

Biological treatment reduced 36% to 76% of BOD from the effluent. Removal of 70% from the effluent of a rubber glove manufacturing factory was reported by Livesay (1995). The primary treatment was more effective in reducing the BOD content as compared to biological treatment. The chemical flocculation treatment removed most of the heavy metals and organic matters up front prior to the biological treatment. The efficiency of BOD removal for both the primary and secondary treatments and the overall removal is expressed in Figure 4.5.

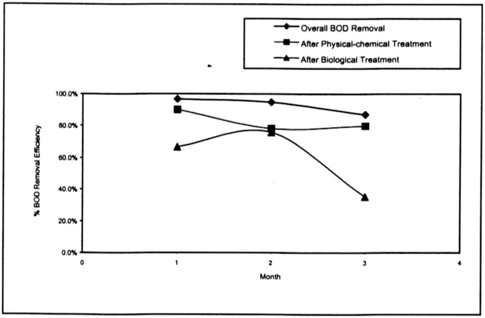

Figure 4.5 : Percentage BOD Removal Efficiency at Different Stages of Effluent Treatment at Factory B

4.3.3 Removal of BOD in Effluent from Factory C

The reduction in BOD was found to be consistent i.e. approximately 82%, which could be due to the consistent inflow of the raw effluent. Factory C generated the highest effluent volume of 1200 m^3 per day, as compared to Factory A and B with effluent volume of 166 m^3 and 1000 m^3 per day, respectively. The monthly average BOD concentration in the raw effluent was also constant, without significant fluctuation as shown in Table 4.4. In addition, the BOD concentration was observed to be lowest among the three factories. There could be many factors that contributed to these observations such as differences in the operation and maintenance of the factory and the WWTP, and many other factors. The operation and maintenance of the WWTP play an important role in determining the effectiveness of the WWTP. Factory C being a larger factory placed emphasis on the maintenance of the plant. All effluent discharged into the WWTP was monitored carefully so as to ensure that the WWTP was working well and the quality of treated effluent adhered strictly to the regulatory requirements. The overall removal of BOD from Factory C effluent was still satisfactory despite recorded a lower efficiency removal compared to Factory A and B.

Table 4.4 : Monthly Average BOD Concentration at Different Stages of Effluent Treatments for Factory C

Month	BOD of Raw Effluent	BOD After Physical-chemical Treatment	% BOD Removed	BOD of Treated Effluent	% BOD Removed	Overall BOD Removal (%)
1	127 ± 9	41 ± 2	68	21 ± 2	49	84
2	188 ± 15	62 ± 7	67	35 ± 0.9	44	81
3	192 ± 15	67 ± 7	65	35 ± 1	48	82

BOD concentrations are expressed in mg/l.

The percentage removal of BOD by the primary treatment was approximately 66%. It was observed that there were fine unsettled flocs being carried over to the aeration tank occasionally during the sampling period. These fine floating flocs were found to be floating in the effluent itself, and could not be removed with DAF. The presence of these flocs indicated that the chemical flocculation process was not functioning effectively. Thus, the BOD levels in the effluent after DAF was at a higher percentage as compared to Factory A and B.

The treated effluent after biological stage was above the limit of Standard A of 20 mg/l but well below limit for Standard B of 50 mg/l. The allowable limit discharge for Factory C is 50 mg/l as it is located at a downstream area. Figure 4.6 showed the BOD concentration of samples collected at different stages of the treatment, while Figure 4.7 indicated the removal efficiencies.

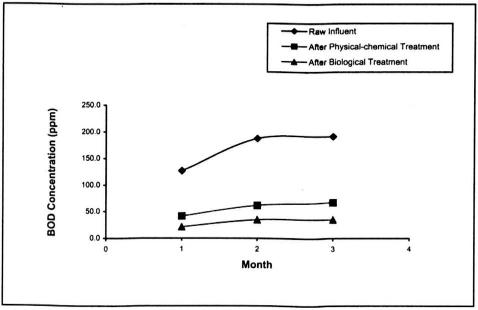

Figure 4.6 : BOD Concentration at Different Stages of Effluent Treatment at Factory C

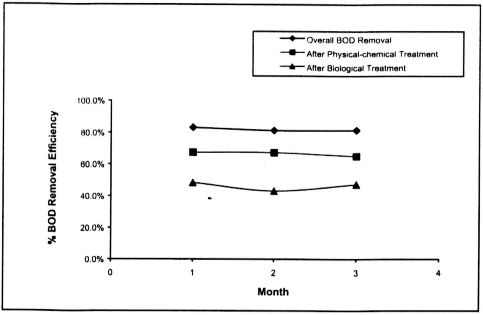

Figure 4.7 : Percentage BOD Removal Efficiency at Different Stages of Effluent Treatment at Factory C

4.4 Removal of COD from Rubber Glove Manufacturing Industries Effluent

Besides BOD concentration, COD concentration in the effluent collected at the equalisation basin, outlet of DAF and outlet of the final clarifier was also analysed. The actual removal of COD by chemical flocculation and DAF system and by biological treatment was measured to determine the COD removal efficiency for all three factories.

4.4.1 Removal of COD in Effluent from Factory A

Results from the study indicated that the COD concentration in the treated effluent was reduced to a range from 10 to 20 mg/l from its raw effluent COD of 590 to 956 mg/l (see Table 4.5). These concentrations are well below the DOE allowable limit for discharge for Standard A of 50mg/l and Standard B of 100 mg/l.

Month 1 recorded the highest percentage of COD removal, registering almost 99%, while Month 4 registered the lowest removal efficiency of 97% (see Table 4.5). In a case study of treatment of examination glove manufacturing effluent by the activated sludge system, percentage removal for COD was equally high i.e. 96% (Zaid, 1993). For comparison, Zaid (1997) reported a 48.4% removal of COD in a study on a WWTP for rubber glove manufacturing plant. The treated effluent has achieved COD level ranging from 11 to 20 mg/l. Subbiah and Alui (1999) observed similar result in their case study of a latex glove factory where the treated effluent has an average COD concentration of 20 mg/l, a significant reduction from the raw effluent COD ranging from 208 to 1210 mg/l.

The combination of chemical flocculation and DAF system has proven to be an effective system as it reduced a minimum of 78% of COD concentration in the raw effluent (see Figure 4.8 and Figure 4.9). This finding indicated that this system is suitable to handle rubber glove manufacturing, as compared to the 48.4% removal by the combination of chemical flocculation and conventional clarifier (Zaid, 1997 and Zaid and Ahmad, 1998).

Table 4.5 : Monthly Average COD Concentration at Different Stages of Effluent Treatments for Factory A

Month	COD of Raw Effluent	COD After Physical-chemical Treatment	% COD Removed	COD of Treated Effluent	% COD Removed	Overall COD Removal (%)
1	956 ± 50	67 ± 5	93	11 ± 0.7	84	99
2	598 ± 30	44 ± 5	93	14 ± 0.5	68	98
3	784 ± 40	97 ± 6	88	15 ± 0.5	85	98
4.	590 ± 18	130 ± 8	78	20 ± 0.6	85	97

COD concentrations are expressed in mg/l.

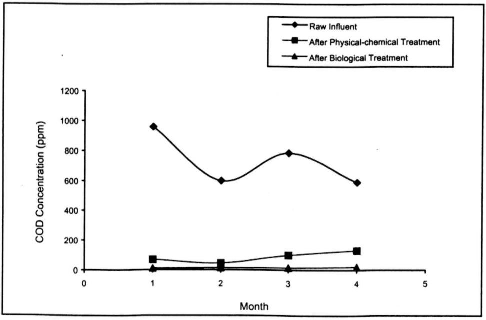

Figure 4.8 : COD Concentration at Different Stages of Effluent Treatment at Factory A

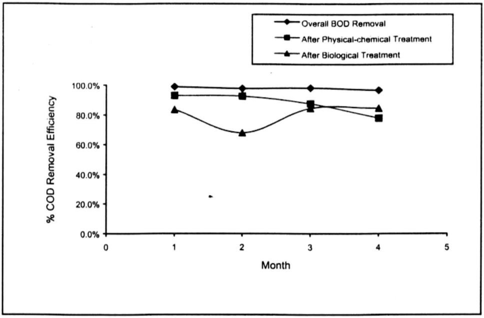

Figure 4.9 : Percentage COD Removal Efficiency at Different Stages of Effluent Treatment at Factory A

As a substantial COD was removed during the primary treatment, the effluent after the biological treatment was further reduced to a very low level, as shown in Table 4.5. Except for Month 2, the percentage COD removal was approximately 84%. While the percentage removal in Month 2 was lower than the rest, the actual value of COD was close for the Months 1 and 3. Overall the COD value for the treated effluent measured throughout the 4 months of study did not exceed the regulatory standards for discharge.

4.4.2 Removal of COD in Effluent from Factory B

The concentration of COD in effluent generated in Factory B was double the COD concentration in effluent from Factory A. The monthly average COD was recorded from 1201 to 2005 mg/l, as shown in Table 4.6. However, these concentrations were still within the range of 98 to 3058 mg/l as reported in a nationwide survey carried out on the 38 rubber glove manufacturing factories (Zaid, 2001). As discussed earlier, COD concentration was noted to be much higher than BOD concentration (Figure 4.10). This was likely due to the presence of lesser biodegradable organic matter compared to the total organic and also the compounds, which were easily oxidised.

Table 4.6 : Monthly Average COD Concentration at Different Stages of Effluent Treatments for Factory B

Month	COD of Raw Effluent	COD After Physical-chemical Treatment	% COD Removed	COD of Treated Effluent	% COD Removed	Overall COD Removal (%)
1	2005 ± 155	206 ± 20	90	65 ± 3	68	97
2	1311 ± 90	306 ± 35	77	73 ± 9	76	94
3	1201 ± 85	411 ± 30	66	68 ± 2	84	94

COD concentrations are expressed in mg/l.

The reduction of COD by primary treatment ranged from 65.8% to 89.7% (see Table 4.6). This is much higher compared to the survey conducted by RRIM on the existing rubber glove manufacturing plants, where the range COD was within 33.1% to 48.7% (Nordin and Zaid, 1997). However, the primary treatment alone was not sufficient and capable enough to reduce the COD content to the permissible limit of discharge for even Standard B.

Thus, biological treatment played an important role in ensuring the reduction of the biodegradable organic matter in the effluent and subsequently reducing the COD concentration (Figure 4.11). For Months 2 and 3, it was noted that the percentage COD removal efficiency by biological treatment was higher whereas it was lower in Month 1. From the observation, a larger amount of organic was removed at the primary stage in Month 1. Again, there could be many factors that lead to this outcome.

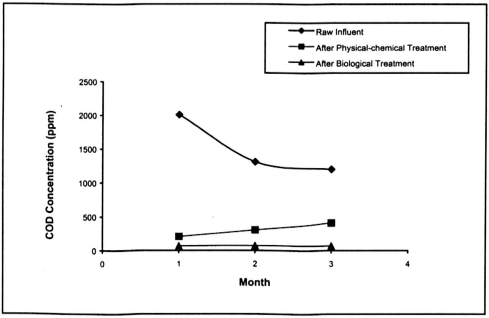

Figure 4.10 : COD Concentration at Different Stages of Effluent Treatment at Factory B

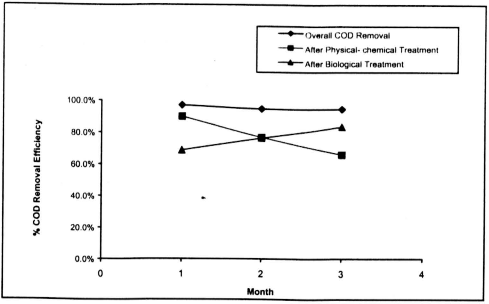

Figure 4.11: Percentage COD Removal Efficiency at Different Stages of Effluent Treatment at Factory B

4.4.3 Removal of COD in Effluent from Factory C

The COD removal trend for Factory C was similar to the BOD removal (Figure 4.12). The COD content in the raw effluent generated from Factory C ranged from 339 mg/l to 373 mg/l with a difference of approximately 10% only. The overall removal varied from 73% to 77%, resulting in treated effluent with average concentration of 83mg/l for Month 1, 86 mg/l for Month 2 and lastly 91 mg/l for Month 3. All these concentrations as shown in Table 4.7, were within the limit of Standard B, and could safely discharged into the public drain or other forms of receiving water.

Table 4.7 : Monthly Average COD Concentration at Different Stages of Effluent Treatments for Factory C

Month	COD of Raw Effluent	COD After Physical-chemical Treatment	% COD Removed	COD of Treated Effluent	% COD Removed	Overall COD Removal (%)
1	339 ± 25	159 ± 10	53	83 ± 5	48	77
2	373 ± 25	168 ± 12	55	86 ± 5	49	77
3	335 ± 26	199 ± 13	44	91 ± 7	52	73

COD concentrations are expressed in mg/l.

The removal of COD in effluent from Factory C was less effective as compared to Factory A and B (see Figure 4.12 and 4.13). Despite the fact that Factory C reported the lowest COD concentration in its raw effluent, the reduction of COD by both the physical-chemical system was only from 44% to 55%. This could be due to the floating flocs being carried over to the biological tank as observed occasionally during the sampling period. Similarly, COD reduction in the secondary stage was fairly good, ranging from 73% to 77%, but could be improved further.

4.5 Removal of SS from Rubber Glove Manufacturing Industries Effluent

Solids in water are undesirable for many reasons. They may adversely affect the quality of water or wastewater. In the case of industrial waste treatment plant effluent, many of the potential uses for reclaiming the water can be severely limited by solids. These solids can accumulate in pipes, and eventually plug them up.

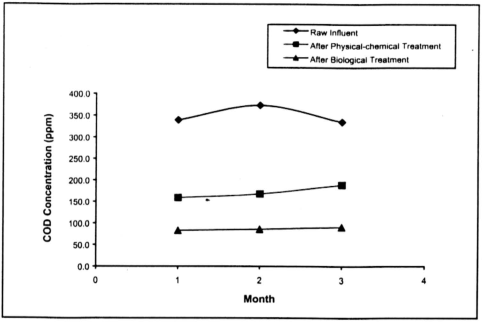

Fig 4.12 : COD Concentration at Different Stages of Effluent Treatment at Factory C

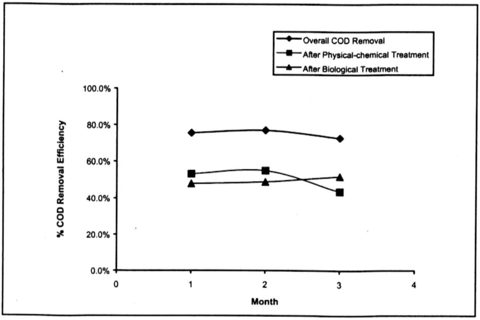

Figure 4.13: Percentage COD Removal Efficiency at Different Stages of Effluent Treatment at Factory C

Waters with high solids content require additional mechanical and chemical treatment, and the cleaning process becomes more expensive. Furthermore, high levels of solids in water increase the water density, affect osmoregulation of freshwater organisms and reduce the solubility of gases such as oxygen. SS in untreated wastewater can lead to sludge deposits and anaerobic conditions in receiving surface waters. Suspended and dissolved solids, both organic and inert are common tests of polluted waters. The terms 'suspended solids' (SS) and 'dissolved solids' (DS) refer to matter that is retained and passed through a standard glass-fiber filter or paper filter, respectively. However, SS is more commonly considered in the studies of wastewater characteristics.

4.5.1 Removal of SS in Effluent from Factory A

The concentration of SS in the raw effluent, after physical-chemical treatment and the biologically treated effluent are shown in Table 4.8. Similar to BOD and COD, the overall removal of SS concentration in the effluent was very good. Monthly average concentration of SS in the treated effluent for the four months of study were well below Standard A of DOE discharge limit (Figure 4.14). In fact the SS level in the treated effluent was reduced to 13 mg/l for Month 2 and 3, 14 mg/l for Month 1 and Month 4. The minimum percentage SS removal was for Month 2 at 97%, while maximum removal was 98%. In his case study on the pollution control in the examination glove manufacturing industries, Zaid (1988) reported removal of 89% and 92% for two of the five selected rubber glove manufacturing factories.

Table 4.8 : Monthly Average SS Concentration at Different Stages of Effluent Treatments for Factory A

Month	SS of Raw Effluent	SS After Physical-chemical Treatment	% SS Removed	SS of Treated Effluent	% SS Removed	Overall SS Removal (%)
1	686 ± 50	35± 5	95	14 ± 2	60	98
2	504 ± 25	40 ± 4	92	13 ± 1	68	97
3	571 ± 30	38 ± 5	93	13 ± 0.8	66	98
4	578 ± 25	45 ± 3	92	14 ± 1	69	98

SS concentrations are expressed in mg/l.

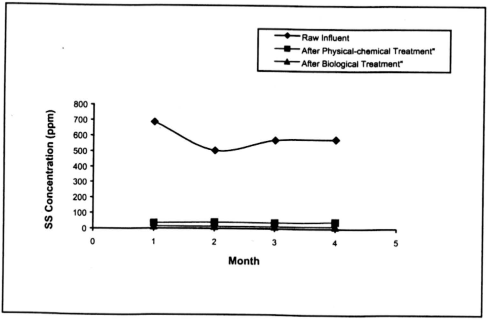

Fig 4.14 : SS Concentration at Different Stages of Effluent Treatment at Factory A

The percentage of SS removal by the primary treatment ranged from 92% to 95% (see Figure 4.15). The chemical flocculation step followed by the DAF system was noted to be very effective in removing the SS content in the raw effluent. Similar or higher effectiveness of chemical flocculation with DAF system was observed in industries such as pet food manufacturer with 99.6% reduction in SS, pet finger processing with 95.7% reduction, cosmetics manufacturer with 97.4% reduction and silk screen printing with 99.6% reduction (Meyers, 1991).

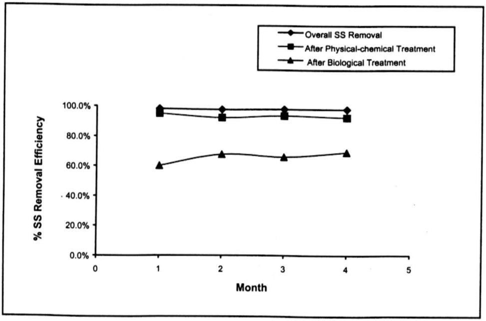

Figure 4.15: Percentage SS Removal Efficiency at Different Stages of Effluent Treatment at Factory A

Observations indicated that biological treatment was less effective in removing the SS in the effluent. As the main function of biological treatment is basically to remove the biodegradable organic matters, the SS matters could not be oxidised by the microorganisms in the biological tank. Therefore, the reduction of SS in the biological tank was far less significant as compared to the chemical flocculation step. Figure 4.15 shows the percentage of SS removal for all three stages of treatment.

4.5.2 Removal of SS in Effluent from Factory B

The monthly average SS concentration in the raw effluent generated from Factory B fluctuated significantly as compared to Factory A. It ranged from 275 mg/l to 1006 mg/l within the three months of study (see Table 4.9). One possible factor that may likely cause the fluctuation was the volume of the incoming effluent.

Table 4.9 : Monthly Average SS Concentration at Different Stages of Effluent Treatments for Factory B

Month	SS of Raw Effluent	SS After Physical-chemical Treatment	% SS Removed	SS of Treated Effluent	% SS Removed	Overall SS Removal (%)
1	1006 ± 70	60 ± 2	94	8 ± 0.5	87	99
2	275 ± 14	30 ± 3	89	10 ± 1	67	97
3	460 ± 25	60 ± 3	87	30 ± 1	50	94

SS concentrations are expressed in mg/l.

The overall removal of SS was found to be satisfactory, with percentage removal ranging from 94% to 99%. However, except for Month 2, the rest of the results indicated that further treatment such the secondary treatment was necessary to ensure that the treated effluent met the allowable limit prior to discharge. The effluent after primary stage for Month 1 and 3 contained 60 mg/l of SS. Primary treatment alone was not sufficient to reduce the SS content in the effluent, particularly with higher concentration of SS in the raw effluent and also with the bigger volume of wastewater. Factory A has lower SS concentration in its effluent and the volume of wastewater generated is 166 m^3 daily as compared to Factory B which generates 1000 m^3 of wastewater daily.

Observations indicated that the biological treatment results were better as compared to treatment in Factory A (see Figure 4.16). The residual SS from the DAF was likely to be oxidised by the microorganisms in the biological tank and thus the concentration reduced the pollutants. Treated effluent for the three months met the DOE's limit of discharge for both Standard A and B. The percentage of SS removal efficiency throughout the 3-month sampling period was indicated in Figure 4.17.

4.5.3 Removal of SS in Effluent from Factory C

Effluent from Factory C contained the lowest SS concentration, as compared to Factory A and B. Throughout the 3 months of study, the average concentration varied from 239 mg/l to 414 mg/l. However, the percentage removal of SS from effluent was the lowest too i.e. 87% for Month 1, 80% for Month 2 and 76% for Month

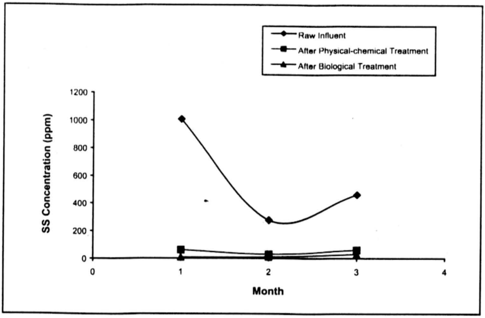

Figure 4.16 : SS Concentration at Different Stages of Effluent Treatment at Factory B

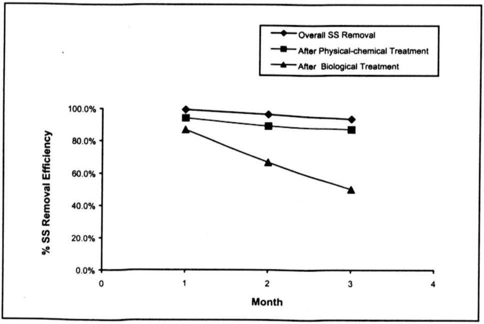

Figure 4.17: Percentage SS Removal Efficiency at Different Stages of Effluent Treatment at Factory B

3. The reduction of SS concentration after each stage of treatment is indicated in Table 4.10. For comparison, Zaid (1993b) reported that the removal of SS in the examination glove manufacturing effluent by the activated sludge system was 65%, while removal of 85% was observed in the treatment of household glove manufacturing effluent by ponding and sand filtration system. Thus, the WWTP system used in treating the effluent generated in Factory C could be considered as suitable.

Table 4.10 : Monthly Average SS Concentration at Different Stages of Effluent Treatments for Factory C

Month	**SS of Raw Effluent**	**SS After Physical-chemical Treatment**	**% SS Removed**	**SS of Treated Effluent**	**% SS Removed**	**Overall SS Removal (%)**
1	239 ± 13	65 ± 15	73	30 ± 2	54	87
2	414 ± 60	156 ± 20	62	81 ± 3	48	80
3	255 ± 20	92 ± 12	64	62 ± 5	33	76

SS concentrations are expressed in mg/l.

As Factory C was required to adhere to the regulatory Standard B discharge limit, the treated effluent for Month 1, 2 and 3 which met the requirements, could be discharged into the public drain without any further treatment.

Generally, the primary treatment has achieved a fairly good removal of SS concentration in the raw effluent. The monthly average removal ranging from 62% to 73%, had indicated that the effluent could even be discharged into the receiving water without going through the secondary treatment on occasions where the SS content in the raw effluent is less than 250 mg/l. However, such short cut is not advisable.

For Factory C, the biological treatment is critical as it helped to further reduce the SS concentration in the effluent prior to discharging into the public drain. SS concentration and percentage of removal at different stages of treatment are shown in Figure 4.18 and 4.19.

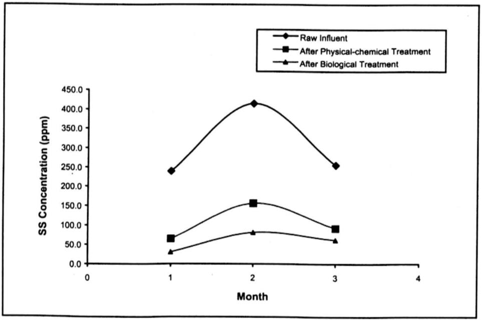

Figure 4.18 : SS Concentration at Different Stages of Effluent Treatment at Factory C

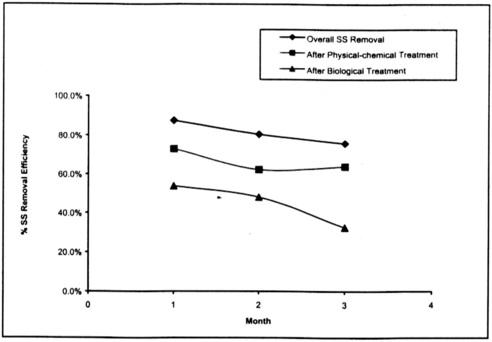

Figure 4.19: Percentage SS Removal Efficiency at Different Stages of Effluent Treatment at Factory C

4.6 Comparative Performance of WWTPs for Factory A, B and C

This study encompassed detailed analyses of three main parameters namely BOD, COD and SS concentrations at three main stages of the WWTP system i.e. the raw effluent, effluent after primary treatment and effluent after biological treatment, for three rubber glove manufacturing factories.

From these detailed analyses, the performance of each factory can be determined and compared with. From the 3-4 months of analyses, average concentrations were taken for each of the parameter and summarised in Table 4.11. Percentage removal efficiency for each of the parameters can be seen in Table 4.12. From these two tables, a comparative exercise among the three factories based on 1) the overall removal efficiency for each parameter and 2) the removal efficiency of the different stages of the WWTPs was determined.

Table 4.11 : Summary of BOD, COD and SS Concentrations (Average value) for Factory A, B and C

Factory	DOE's discharge limit	BOD Concentration			COD Concentration			SS Concentration		
		I	II	III	I	II	III	I	II	III
A	20	259	54	6	732	85	15	585	40	14
B	50	357	59	23	1506	308	69	580	50	16
C	50	169	57	31	349	172	87	303	104	58

Note: I – Raw Effluent

II – After Physical-chemical Treatment

III – After Biological Treatment

All parameters are expressed on mg/l.

Table 4.12 : Summary of Percentage Removal Efficiency of BOD, COD and SS (Average value) for Factory A, B and C

Factory	Capacity of WWTP (cu.m/d)	% Removal Efficiency of BOD			% Removal Efficiency of COD			% Removal Efficiency of SS		
		I	II	III	I	II	III	I	II	III
A	166	98	79	88	98	89	82	98	93	66
B	1000	94	84	61	95	80	78	97	91	68
C	1200	82	66	46	75	51	50	81	66	45

Note: I – Overall reduction

II – After Physical-chemical Treatment

III – After Biological Treatment

4.6.1 Removal Efficiency of BOD

Among the three factories, volume of effluent generated from the manufacturing processes of Factory A was the lowest, with a daily volume of 166 m^3. Both Factory B and C generated higher volume of wastewater, with 1000 m^3 daily and 1200 m^3 daily, respectively. Nevertheless the concentration of BOD effluent was found to be the highest in the raw effluent from Factory B. The concentration of biodegradable organic matters does not necessarily be proportionate with the volume of effluent generated from the factory.

From Table 4.11 it was observed that that the concentration of BOD of the effluent after primary treatment was at around 55 mg/l. Factory B had the highest percentage of BOD removal as compared to Factory A and C. In fact Factory C has the lowest removal efficiency with an average of 66%. As discussed earlier, very fine and unsettled flocs being carried over to the aeration tank on some occasions during the sampling period were observed. The presence of these floating flocs indicated that the chemical flocculation process was not functioning effectively.

The percentage removal of BOD in the effluent from Factory C by the biological treatment was at an average of 46%, while an average of 88% was recorded for

Factory A. One factor that might contribute to this observation was the manufacturing processes involved for each of the factories. Further information on the processes involved in the manufacturing could not be obtained from these factories due to their confidentiality and commercial issues.

Overall observations showed that the treated effluents from all three factories were able to comply with the regulatory standards of DOE of either Standard A or B. Data collected pointed out that the treated effluent from Factory A demonstrated the lowest BOD level, while treated effluent from Factory C had the highest level. This means that the WWTP of Factory C was the least effective in reduction of BOD from its wastewater. It had an 82% removal compared to Factory A with 98% removal. However, the removal of BOD by the combination chemical flocculation-DAF as primary treatment, followed by an extended aeration system, as secondary treatment had been proven effective and satisfactory. In a report of performance of the flocculation and aeration systems in the treatment of examination glove manufacturing industries effluent, removal of BOD was 95% and 99% (Zaid, 1997). The similarity confirms that the combination of chemical flocculation-DAF system and followed by extended aeration system was suitable for the removal of BOD from rubber glove manufacturing industries effluent.

Average percentage removal of BOD at different stages of treatment for Factory A, B and C is shown in Figure 4.20.

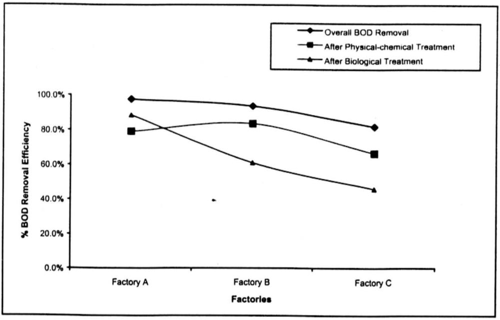

Figure 4.20 : A Comparison of BOD Removal Efficiency at Different Stages for Effluent Treatment at Factory A, B and C.

4.6.2 Removal Efficiency of COD

Similar observation was noted for the COD concentration in the raw effluent generated by the three factories. Factory B had recorded the highest COD concentration with an average 1506 mg/l, followed by Factory A with an average 732 mg/l. Though the volume of effluent generated by Factory C was the highest, its content was found to have less pollutant. The low reading of BOD and COD in its raw effluent proved this observation as compared to the other two factories.

As listed in Table 4.11, the effectiveness of primary treatment in reducing the COD level in the effluent was fairly good. Factory A had recorded the highest COD removal with 89%. Again, the primary treatment for Factory C was the least effective as compared to Factory A and B. This could be due to the unsettled flocs observed in the DAF unit. Coincidentally the BOD removal was also low for Factory C. Thus, a separate and more detailed study on the chemical flocculation is proposed to be carried out in order to improve on the removal efficiency of pollutants from its effluent.

The biological treatment had managed to further reduce the COD level to the permissible regulatory requirements of standard A for Factory A and Standard B for Factory B and C. Factory A had an average of 82% reduction, Factory B had an average of 78% reduction and lastly an average of 50% reduction for Factory C. In a case study involving the treatment of natural rubber latex concentrate wastewater by stabilisation pond, which is another form of biological treatment, the COD reduction was 63% (Madhu *et. al*, 1994). Zaid (1994) reported a 82% and 47% removal of COD for the treatment of swimming cap manufacturing effluent by the anaerobic/facultative ponding system and treatment of household glove manufacturing effluent by ponding and sand filtration system. As the results of this study were within the range of the findings of other systems, thus, extended aeration system is recommended to be used to treat rubber glove manufacturing effluent in particular.

Treated effluents from all three factories were within the DOE's limit of discharge. From Table 4.12, similar trend of efficiency was observed in the overall reduction of COD compared to BOD reduction. Factory A was noted to have an excellent reduction in COD level (98%), which means that its WWTP system was performing efficient in reducing the pollutants in the effluent generated from the factory itself. Factory B achieved an equally good COD reduction, in fact better than the BOD reduction (see Figure 4.21). Even though treated effluent from Factory C was just slightly below the Standard B of 100 mg/l limit, the results indicated that the this design of WWTP is still suitable to treat effluent from rubber glove manufacturing industries. In a study involving the treatment of rubber glove manufacturing industries effluent by a combination of chemical flocculation-conventional clarifier followed by anaerobic and aerobic fluidised bed, the removal of COD was found to be 48.4% (Zaid, 1997).

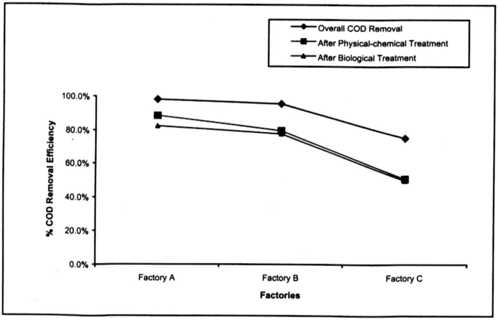

Figure 4.21 : A Comparison of COD Removal Efficiency at Different Stages for Effluent Treatment at Factory A, B and C.

The overall observation confirmed that the selected design for these three factories, involving the usage of DAF in the primary treatment and extended aeration system in the secondary treatment, is suitable for this type of effluent. The significant reduction in COD level indicated that this treatment system was able to remove pollutants particularly the organic pollutants in the rubber glove manufacturing wastewater.

4.6.3 Removal Efficiency of SS

The concentration of SS in the effluent generated from Factory A and B were alike, registering an average of 585 mg/l and 580 mg/l respectively, despite the wide difference in the effluent volume generated daily (see Table 4.11). While there was quite a significant difference in the concentration of BOD and COD between these two factories effluent, in the case of SS presence in the effluent for both the factories was almost similar. However, the concentration in the Factory C's effluent was much lesser even though it produced 1200 m^3 of wastewater daily.

Among the three parameters selected for this study, the primary treatment was found to be most effective in the reduction of SS in the effluent. Both Factory A and B reported an average percentage removal of 93% and 91% respectively, as shown in Table 4.12. These high percentages showed that quite a substantial quantity of solids in the effluent was flocculated out and removed at the DAF unit prior to entering the extended aeration tank. Meyers (1995) reported similar removal efficiency in a case study on the treatment of condom manufacturing effluent using DAF at the primary treatment.

The average percentage removal of SS by the biological treatment was 66%, 68% and 45% for Factory A, B and C respectively. The efficiency removal of SS by biological treatment was lower compared to the BOD and COD. The inability of the microorganisms of degrading the SS indicated that most of the solids were not biodegradable.

Generally, the overall removal of SS from the rubber glove manufacturing effluent at these three factories was very encouraging. The reduction of more than 97% for Factory A and B was higher compared to the 89% and 92% SS reduction as reported by Zaid (1997). The treated effluent of Factory B had managed to achieve SS concentration below the DOE's discharge limit of Standard A even though its requirement was to meet Standard B. A similar trend of reduction was noted in the case of Factory A and B where both had similar SS concentration in their raw effluent. Though nothing conclusive could be said at this moment of time, this might be a good start in future studies, to further determine if there is such a trend in the reduction of SS in this type of effluent. Average percentage removal of SS at different stages of treatment for Factory A, B and C is shown in Figure 4.22.

As in the case of BOD and COD removal, this design with the combination of chemical flocculation with DAF and activated sludge system, was also suitable for the reduction of SS pollutants in the effluent of rubber glove manufacturing industries.

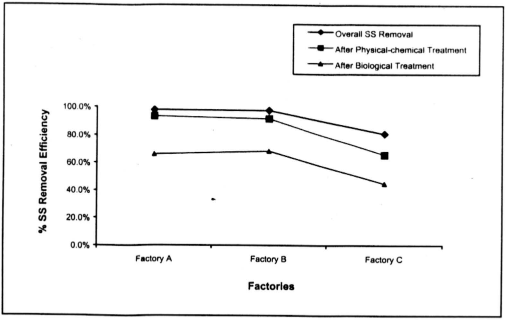

Figure 4.22 : A Comparison of SS Removal Efficiency at Different Stages for Effluent Treatment at Factory A, B and C.