Chapter 5

Discussion, Conclusions & Recommendations

5.1 Discussion

5.1.1 Flow rate and Crepe Rubber Production Capacity:

The designed flow rate of the ETP at Eheliyagoda Rubber Factory is $50m^3/d$ and for the ETP at Parakaduwa Factory it is $60m^3/d$. The average flow rates during the study period for Eheliyagoda rubber factory and Parakaduwa Rubber Factory are $30m^3/d$ and $60m^3/d$ respectively. Due to the reduced flow rate of the Eheliyagoda Factory, hydraulic retention times of the biological treatment units are increased from six to ten days for MAL and three to five days for Maturation pond. ETP of the Parakaduwa Factory runs its original designed capacity. The average crepe rubber production capacity for Eheliyagoda Factory is 789.5kg/d and Parakaduwa Factory it is 1401.2kg/d.

The high quantity of wastewater generated from the crepe rubber production process has always been observed in both rubber factories.

In Eheliyagoda Factory for one tonne of crepe rubber production, wastewater generated is about $38m^3$ and for Parakaduwa Factory it is about $43m^3$.

However as described in the Industrial Pollution Control Guidelines for Natural Rubber Industry (1992), for the production of one tonne of crepe rubber, the average wastewater production including serum water is 32m3. Therefore it is observed that the Eheliyagoda Factory uses 19% more water and the Parakaduwa Factory uses 34% more water than the water quantity stated in the Guidelines for Natural Rubber Industry. Since the Parakaduwa Factory uses more water than the Eheliyagoda Factory, the wastewater generated is more dilute in Parakaduwa Factory than that of the Eheliyagoda Factory.

5.1.2 Characteristics of influent to each ETP:

Even though flow proportionate composite samples would have given better representative samples, due to the practical difficulty of sampling and transport of samples, grab samples taken from the collection tanks were used for the analysis.

During the study period the general characteristics of influent BOD_5 to ETP at Eheliyagoda Factory varied from 620 mg/l to 1280 mg/l and the average influent value of BOD_5 is about 878 mg/l with the standard deviation of 226. The COD values of the influent to the ETP at Eheliyagoda Factory has always been observed in the range of 3100mg/l to 6400mg/l and the average value is 4656mg/l with the standard deviation of 1249. When considering the characteristics of influent BOD_5 at the Parakaduwa Factory it is varied from 450mg/l to 1080mg/l and the average value of influent BOD_5 is 787mg/l with the standard deviation of 191. The COD values of the influent of the ETP at Parakaduwa Factory vary from 5200mg/l to 1600mg/l and the average is 3730mg/l with the standard deviation of 993. While the considerable variation of the influent characteristics are observed in both systems, and the influent characteristics of the Eheliyagoda factory shows higher variation than that of the Parakaduwa Factory. This range variation is a burden to the biological process like activated sludge process, as the system cannot adopt quickly to such changes. These variations of the characteristics of influent may be due to the changes in weather pattern. Latex tapping activities are generally affected by the weather and the quantities of latex production are decreased with the adverse weather condition. In year 2001 the study area has been experiencing heavy rain during April and May and then from May to August, the amount of rain received decreased gradually.

An equalization tank can be used to overcome the operational problems caused by variations of the influent wastewater flow rate and strength, to improve the performance of the downstream processes and to reduce the size and cost of downstream treatment facilities. Apart from improving the performance of most treatment operations and processes equalization tank is an attractive option for upgrading the performance of overloaded treatment plants. The correct volume required for flow rate equalization is determined by using an inflow mass diagram in which the cumulative inflow volume is plotted verses the time of the day. (Matcalf & Eddy, 1995)

Both these treatment systems, which do not have an equalization facility, consist of collection tanks where the capacities are $15m^3$ in Eheliyagoda Factory and $40m^3$ in Parakaduwa Factory.

Since the ETP at Parakaduwa Factory is an activated sludge system, which is more sensitive than mechanical aerated lagoon system, and it operates at its maximum flow rate, installation of an equalization tank prior to biological treatment units can be recommended to improve the performance of this system.

pH of the wastewater generated in both factories is acidic and always it is less than 6.0. As described in chapter 2, for anaerobic treatment the effective pH range is pH 6.4 – 7.2 (Eckenfeder 1989) and for the general range of operation of aeration system is between pH 6.5 and 8.5. As per the table 4.3 in chapter 4, BOD_5 and COD removal efficiencies of the anaerobic treatment in both treatment plants are less than 30%. This shows that the anaerobic treatment process in both treatment plants is not operated efficiently. In both treatment processes lime is added to neutralize the wastewater. In Eheliyagoda Factory lime is added to the first compartment of the anaerobic tank and Parakaduwa Factory it is added to the serum collecting tanks. Low efficiency of anaerobic treatment in both treatment processes may be due to inadequate neutralization (alkalinity) of the wastewater. Therefore both systems should have an adequate collection capacity with pH correction of raw wastewater.

5.1.3 Characteristics of the treated wastewater of each ETP:

During the study period the average effluent BOD_5 of the ETP at Eheliyagoda Factory is 53 mg/l with the standard deviation of 17, and 60% of the BOD_5 readings meet the CEA standards of 50 mg/l. In Parakaduwa Factory the average effluent BOD_5 of this ETP is about 77mg/l with the standard deviation of 23, and 22% of the BOD_5 readings of the effluent obtained during the study period meet the CEA standards of 50mgl. The average effluent COD value of Eheliyagoda Factory is 229mg/l with the standard deviation of 75 and for Parakaduwa Factory it is 340mg/l with the standard deviation of 80. The results of the treated effluent of Eheliyagoda Factory show that 90% of the COD readings meet the CEA standards of 400mg/l and for Parakaduwa Factory, 78% of the COD readings meet the CEA standards.

The average TSS values of the effluent of the effluent treatment plants at Eheliyagoda Factory and Parakaduwa Factory are 315mg/l and 171mg/l respectively. The TSS of the treated wastewater of both treatment systems are exceeding the standard of 50mg/l. The high TSS value of the ETP at Eheliyagoda Factory may be due to high algae content in the ponds. The bulking sludge condition where the settling is retarded and cell escape in the effluent may be the reasons for the high TSS in the effluent of Parakaduwa Factory.

It is noticeable that the variations of the treated wastewater characteristics except TSS are lower in Eheliyagoda Factory than that of the Parakaduwa Factory.

5.1.4 Removal efficiency:

Total BOD_5, COD & TSS removal efficiencies of the ETP at Eheliyagoda Factory are 93.5%, 94.5% and 67.5% respectively. The ETP at Parakaduwa Factory such removal efficiencies are 90.5%, 91.3% and 68.3% respectively. In both treatment systems BOD_5 and COD removal efficiencies are exceeding 90%, but TSS efficiency is less than 70%.

Both effluent treatment systems consist of anaerobic treatment followed by aerobic/ facultative type treatment. Therefore only difference between these two treatment systems is the aerobic/facultative type treatment unit. In ETP at Eheliyagoda Factory this aerobic/facultative type biological treatment is lagoon/pond system where the mechanical aerated Lagoon followed by a maturation pond, but in ETP at Parakaduwa Factory it is an activated sludge aeration tank followed by a clarifier.

In addition to the above, ETP at Parakaduwa Factory consists of a sand bed as a last treatment unit where the average TSS removal efficiency is 78%.

Average BOD_5, COD & TSS removal efficiencies of MAL in the ETP at Eheliyagoda are 77.3%, 79.7% and 48.6%. Average BOD_5, COD & TSS removal efficiencies of Activated Sludge Process in the ETP at Parakaduwa Factory are 73.2%, 76.2% and 44.2%.

As pointed out by Arceivala (1986), BOD removal efficiency for a MAL (facultative type) and an activated sludge process are 70- 90% and 85-93% respectively.

In the activated sludge process of the Parakaduwa Factory BOD removal efficiency is less than the value mentioned in the literature, and in the mechanical aerated lagoon process BOD_5 & COD removal efficiencies are within the range mentioned in the literature. When comparing these two systems, removal efficiencies of BOD_5, & COD of the mechanical aerated lagoon are higher than that of the activated sludge process.

5.1.5 Process control of the Activated Sludge Process at Parakaduwa Rubber Factory:

As pointed out in chapter 2, an activated sludge process needs very good process control to achieve high levels of treatment performance than the mechanical aerated lagoon system. The MLSS, F/M ratio, DO level and SVI of the aeration tank are the main factors that can be used to control the activated sludge process.

MLSS values have been observed in the range of 3950mg/l and 5800mg/l and this values center around 4911mg/l. As discussed in chapter 2, a good floc in the aeration tank might be formed in mixed liquor at 3000mg/l of suspended solids. The high MLSS concentrations observed during the study period may be one reason for the bulking in the activated sludge process. Table 4.5 also shows the F/M ratio and it has been in the range of 0.16 to 0.23 per day with an average of 0.19 per day. The theoretical F/M ratio usually required for proper performance in an activated sludge plant is 0.6 per day in warm climatic countries

(Arceivala 1994). This low F/M ratio has resulted due to the high-suspended solids concentration or high MLSS concentration prevailing in the aeration tank during the study period.

As shown in table 4.6 in chapter 4, the DO level in the aeration tank has always been less than 1mg/l. The amounts of DO required for treating wastewater depends on the oxygen demand of the microorganisms in the sludge, which oxidize both carbonaceous and nitrogenous wastes. As discussed in chapter 2, an adequate mixed liquor dissolved oxygen concentration for a nitrifying plant, it is 2mg/l (Horan, 1990).

Average value of the SVI is 108 and it is in the desirable range. As discussed in chapter 2 this value may be due to high MLSS concentrations in the aeration tank and this higher MLSS value is not desirable. Therefore the SVI values obtained during the study period do not show the actual picture of sludge conditions. The settled sludge volume in 30 minutes was 538ml of the 1000ml-graduated cylinder. As highlighted in the literature, a good floc in the aeration tank would settle to 25% of its original volume in 30 minutes, which corresponds to 250ml of the 1000ml graduated cylinder. Thus the settled sludge volume (in 30 minutes) should be less than 250ml for a good floc. The value of 538ml obtained shows that the floc formed in the aeration tank is not a well settling floc.

5.1.6 Unit Cost Calculations & Cost Comparison of the Treatment Processes

As shown in table 4.10 in chapter 4, the capital investment for the treatment of $50m^3$ of rubber effluent through mechanical aerated lagoon system at Eheliyagoda Factory is Rs. 3,509,574.00 while that of treating $60m^3$ of rubber effluent through activated sludge system at Parakaduwa Factory is Rs 2,802,183.00. For comparison, considering the treatment $60m^3$ of raw rubber effluent of mechanical aerated lagoon system and activated sludge system are Rs.4, 211,488.80 and Rs.2, 802,183.00 respectively. That is the capital cost of the treatment system at Parakaduwa Rubber Factory is 66.5% of the capital cost of the treatment system at Eheliyagoda Factory. Therefore the initial capital cost of the activated sludge process at Parakaduwa Factory is lower than the mechanical aerated lagoon system at Eheliyagoda Factory.

When comparing the total annual cost for operation and maintenance of the treatment systems (table 4.10 in chapter 4), it is lower in the mechanical aerated lagoon system and this cost for the treatment system at Eheliyagoda is 54.5% of the operation & maintenance cost used for the activated sludge system at Parakaduwa Factory.

If we compare the unit cost calculation for the period of 10 years of the operation of the treatment plant in terms of Rs/m3 of wastewater treated, those values do not reflect the true picture because of the higher water usage in the production process of crepe rubber at Parakaduwa Factory than the Eheliyagoda Factory. While the Parakaduwa Factory uses 5m3 more water than the Eheliyagoda Factory to produce one tone of crepe rubber, the raw effluent for treatment at Parakaduwa Factory is more diluted than the raw effluent generated in Eheliyagoda Factory. Therefore the better indication of the unit cost calculation would be obtained by comparing the cost in terms of Rs / kg dry rubber produced and in terms of Rs/kg of BOD treated.

As illustrated in table 4.11, when both plants are operating at their designed flow rates, for the period of 10 years of the operation of the plants, the wastewater treatment cost for the production of 1kg crepe rubber at Parakaduwa Factory and Eheliyagoda Factory are Rs1.59 and Rs1.53 respectively. Also the one-kilogram of BOD load treatment cost of the ETP at Eheliyagoda Factory and Parakaduwa Factory are Rs. 46.14 and Rs. 47.11 respectively. Therefore when comparing wastewater treatment costs for the period of 10 years of the effluent treatment plants, treatment cost through the activated sludge process is higher than that of the treatment at Eheliyagoda. Also the effluent treatment processes like activated sludge processes are energy consuming processes which require considerable skill in installation, operation and maintenance. For the developing country like Sri Lanka where there is a national effort to save energy, low energy using methods such as lagoon/pond systems are more important in wastewater treatment.

5.2 Conclusions

1. In both treatment systems BOD_5 & COD variations of the influent were observed according to the weather conditions prevailing during the study period.

2. The efficiency of the anaerobic treatment unit in both cases is very low and it is less than 30%. According to Metcalf & Eddy in 1995, COD removal of the anaerobic process used for the treatment of industrial waste is about 75 – 85%. Further study of the anaerobic treatment unit should be carried out in order to improve the efficiency of it.

3. Treatment efficiency of the mechanical aerated lagoon at Eheliyagoda Factory is higher than that of the treatment efficiency of the activated sludge process at Parakaduwa Factory.

4. The 60% BOD_5 and 90% COD results of the treated wastewater obtained through the ETP at Eheliyagoda Factory has conformed to CEA standards. In Parakaduwa Factory 22% BOD_5 and 78% COD results of the treated wastewater has conformed to CEA standards. With respect to TSS, Eheliyagoda Factory has not met CEA standard at all where as only 44% of data of ETP at Parakaduwa Factory met the CEA standard. Hence both treatment systems should be upgraded to achieve CEA Standards as per the NEA.

5. Though the initial construction cost is low in the ETP at Parakaduwa Rubber Factory, overall wastewater treatment cost for 1kg of dry rubber produced and 1kg of BOD treated are slightly higher than the ETP at Eheliyagoda Rubber Factory.

6. DUE to the low operational & maintenance cost and high treatment efficiency of MAL system, it can be concluded that the mechanical aerated lagoon system is more cost effective wastewater treatment process for natural rubber industry where the land is available.

5.3 Recommendations:

a) Following steps are recommended in order to improve the performance of the two treatment plants.

1. Periodical checks (weekly) on DO, nutrients & pH in the aeration tank and pH, BOD_5, COD & TSS of the wastewater after the aerobic treatment of ASP should be carried out to obtain the information on the performance of the ASP.

2. Capacities of the collection tanks should be increased in both treatment systems to collect total quantity of wastewater generated per day.

3. Since the raw wastewater generated during the production process is acidic in nature, daily pH corrections of the wastewater in collection tanks of both treatment processes should be carried out in order to achieve an efficient anaerobic treatment.

4. In the treatment process at Parakaduwa Factory, DO concentration is low in the Aeration tank and it is very important to increase DO to overcome the problems such as bulking and have complete oxidation of carbonaceous matter. The aeration process of the ETP

should be upgraded or replaced with diffused air aeration instead of mechanical surface aerators to achieve the required DO level.

5. As discussed in chapter 2, a good floc in the aeration tank of ASP might be formed in mixed liquor at 3000mg/l of suspended solids. MLSS concentration in the aeration tank at Parakaduwa Factory should be maintained in the range of 3000 – 4000mg/l by maintaining the recycle rate in order to avoid bulking sludge.

6. The MLSS and SVI values of the aeration tank at Parakaduwa Factory should be determined daily in order to adjust the recycle sludge rate.

7. As a short-term control of activated sludge bulking in the aeration tank at Parakaduwa Factory, return sludge line should be mixed with Hydrogen Peroxide to suppress the excessive growth of filamentous organisms.

8. Settled sludge in Maturation Pond in Eheliyagoda Factory should be removed in regular manner.

9. Sand filter bed should be installed as a last treatment unit of the ETP at Eheliyagoda Factory, in order to reduce the high concentrations of solids in the treated effluent.

10. Effluent Treatment Plant Operator should be given an adequate knowledge on the ETP and the treatment process, specially the ASP that needs a proper processed control, in order to run the plant successfully.

11. Biological Inventory on microorganism group types could be adopted for the aeration tank at Parakaduwa Rubber Factory to assess the treatment process and to carry out early steps to prevent sludge bulking.

12. Additional one unit of pumps & aerators should be kept in the factory to replace when there is any failure of such equipment.

13. As an energy conservation step, during the designing period all treatment units of an ETP should be planned to obtain gravity flow instead of having pumping units, wherever possible.

b) Followings are recommended to be studied further

1 Further research is needed to reduce the construction cost of a mechanical aerated lagoon system for natural rubber effluent.

2 Further studies are needed to improve the efficiency of anaerobic treatment.

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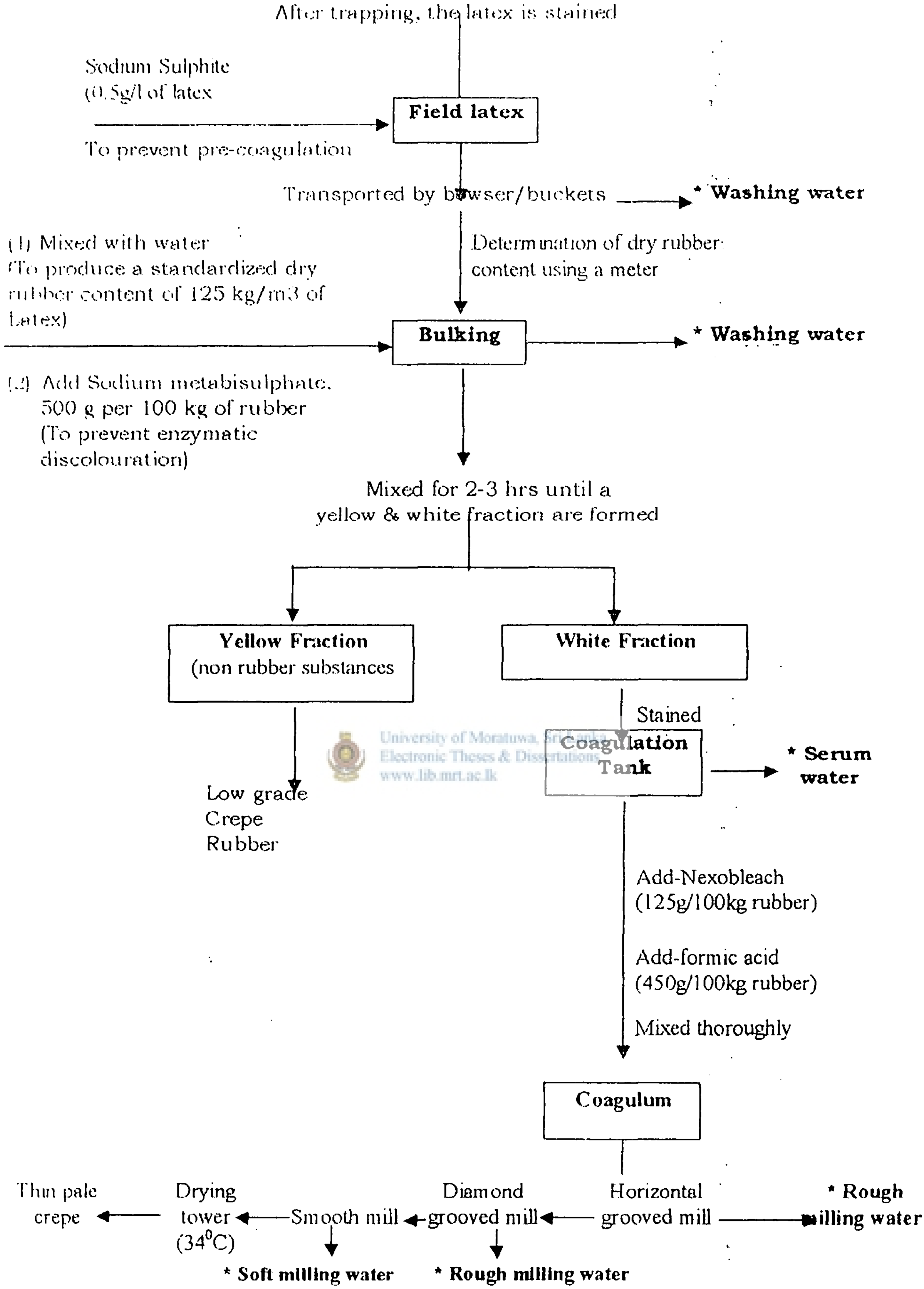
Appendix 1.1 – Production Process & Wastewater Generation Points



Appendix 1.2

Tolerance limits for effluents from Rubber factories discharged into Inland Surface waters

No.	Determinants	Tolerance Limit	
		Type I * Factories	**Type II ** Factories**
1	PH value at ambient temperature	6.5 to 8.5	6.5 to 8.5
2	Total suspended solids, mg/l, max	100	100
3	Total solids, mg/l, max	1500	1000
4	Biochemical Oxygen Demand (BOD_5) in five days at 20°C, mg/l, max	60	50
5	Chemical Oxygen Demand (COD), mg/l, max	400	400
6	Total Nitrogen, mg/l, max	300	60
7	Ammoniacal Nitrogen, mg/l, max	300	40
8	Sulfides, mg/l, max	2.0	2.0

* Type I Factories - Latex concentrate
** Type II Factories - Standard Lanka Rubber; Crepe Rubber and Ribbed smoked sheets

Note I All efforts should be made to remove colour and unpleasant odour as far as practicable.

Note II These values are based on dilution of effluents by at least eight volumes of clean receiving water. If the dilution is below eight times, the permissible limits are multiplied by one eighth of the actual dilution.

Appendix 4.1

Biological Reactor dimensions of each treatment system:

Rubber Factory	Reactor type	Width (m)	Length (m)	Depth (m)	Volume (m)
Eheliyagoda Rubber Factory	Anaerobic tank	6.94	6.94	1.68	60
	Mechanical aerated pond	12.3	22.3	1.5	300
	Maturation pond	9.35	7.34	1.5	150
Parakaduwa Rubber Factory	Anaerobic tank	6.0	6.19	2.9	107.7
	Activated sludge tank	3.0	6.6	3.3	65.34
	Clarifier Diameter- 2.5m Height - 3.3m				

Hydraulic Retention Time = V/Q

Rubber Factory	Type of reactor	Calculated value
Eheliyagoda Rubber Factory	Anaerobic tank	$60m^3/30m^3.d$ = 2 days
	Mechanical aerated pond	$300m^3/30m^3.d$ = 10 days
	Maturation pond	$150m^3/30m^3.d$ = 5 days
	Total retention time	**17 days**
Parakaduwa Rubber Factory	Anaerobic tank	107.7m3/67.5m3.d = 1.6 days
	Aeration (activated sludge) tank	60m3/67.5 m3.d = 0.9 days;(21.6 hrs)
	Total retention time	**2.5 days**

Appendix 4.2

B.O.Q. and Estimate for the civil works Of the treatment plant at Eheliyagoda Rubber Factory:

Description	Unit	Qty	Rate	Amount
I. Collection Tank & R. traps				
a. Excavation	Cube	5.14	1,500.00	7,710.00
b. 3"thick 1:3:6 lean concrete	Cube	0.36	17,000.00	6120.00
c. Form work	Sqrs	4.71	5,500.00	25,905.00
d. Reinforcement (Y_{10})	Cwt	6.00	3,300.00	19,800.00
e. 1:2:4:(¾") R.C.Concrete	Cube	1.72	19,000.00	32,680.00
f. Smooth Cement Plaster (including water proofing work)	Sqrs	3.99	2,500.00	9,975.00
2. Anaerobic Tank				
a. Excavation	Cube	22.00	1,500.00	33,000.00
b. 3" thick 1:3:6 lean concrete	Cube	1.00	17,000.00	17,000.00
c. Form work	Sqrs	11.80	5,500.00	64,900.00
d. Reinforcement (Y_{10})	Cwt	24.9	3,300.00	82,170.00
e. 1:2: 4: (¾") R. C. Concrete	Cube	4.88	19,000.00	92,720.00
f. Smooth Cement Plaster (including water proof work)	Sqrs	10.45	2,500.00	26,125.00
3. Mechanical Aerated Lagoon				
a. Excavation	Cube	138.82	1,500.00	208,230.00
b. 3" thick 1:3:6 lean concrete	Cube	9.42	17,000.00	160,140.00
c. Form work	Sqrs		5,500.00	63,690.00
d. Reinforcement (Y_{10})	Cwt	94.62	3,300.00	312,246.00
e. 1:2:4: (¾ ") R. C. Concrete	Cube	37.71	19,000.00	716,490.00
f. Smooth Cement Plaster (including water proof work)	Sqrs	40.02	2,500.00	100,050.00
4. Maturation Pond				
a. Excavation	Cube		1,500.00	57,795.00
b. 3" thick 1:3:6 lean concrete	Cube		17,000.00	55,080.00
c. Form work	Sqrs		5,500.00	32,230.00
d. Reinforcement (Y_{10})	Cwt		3,300.00	100,518.00
e. 1:2:4: (¾") R.C. Concrete	Cube		19,000.00	204,440.00
f. Smooth Cement Plaster (including water proof work)	Sqrs		2,500.00	34,975.00

Appendix :4.3

B.O.Q. and Estimate for the civil works of treatment plant at Parakaduwa Rubber Factory:

Description	Unit	Qty	Rate	Amount
I. <u>Collection Tank & R. traps</u>				
a. Excavation	Cube	21.76	1,500.00	32,640.00
b. 3"thick 1:3:6 lean concrete	Cube	0.65	17,000.00	11,050.00
c. Form work	Sqrs	13.53	5,500.00	74,415.00
d. Reinforcement (Y_{10})	Cwt	22.89	3,500.00	80,115.00
e. 1:2:4:(¾") R.C.Concrete	Cube	4.70	19,000.00	89,300.00
f. Smooth Cement Plaster (including water proofing work)	Sqrs	9.94	2,500.00	24,850.00
2. <u>Anaerobic Tank</u>				
a. Excavation	Cube	46.33	1,500.00	60,294.00
b. 3" thick 1:3:6 lean concrete	Cube	1.22	17,000.00	20,740.00
c. Form work	Sqrs	22.18	5,500.00	121,990.00
d. Reinforcement (Y_{10})	Cwt	53.72	3,300.00	177,276.00
e. 1:2: 4: (¾") R. C. Concrete	Cube	11.83	19,000.00	224,770.00
f. Smooth Cement Plaster (including water proof work)	Sqrs	17.73	2,500.00	44,352.00
3. <u>Aeration Tank</u>				
a. Excavation	Cube	22.53	1,500.00	33,795.00
b. 3" thick 1:3:6 lean concrete	Cube	0.52	17,000.00	8,840.00
c. Form work	Sqrs	6.18	5,500.00	33,990.00
d. Reinforcement (Y_{10})	Cwt	28.31	3,300.00	93,432.00
e. 1:2:4: (¾ ") R. C. Concrete	Cube	6.38	19,000.00	121,220.00
f. Smooth Cement Plaster (including water proof work)	Sqrs	7.97	2,500.00	19,925.00
4. <u>Sedimentation Tank</u>				
a. Excavation	Cube	5.40	1,500.00	8,100.00
b. 3" thick 1:3:6 lean concrete	Cube	0.08	17,000.00	1,360.00
c. Form work	Sqrs	5.71	5,500.00	31,405.00
d. Reinforcement (Y_{10})	Cwt	11.45	3,300.00	37,785.00
e. 1:2:4: (¾") R.C. Concrete	Cube	2.27	19,000.00	43,130.00
f. Smooth Cement Plaster (including water proof work)	Sqrs	2.84	2,500.00	7,100.00
5. <u>Sand Bed</u>				
a. Excavation	Cube	2.69	1,500.00	4,035.00
b. 3" thick 1:3:6 lean concrete	Cube	0.15	17,000.00	2,550.00
c. Form work	Sqrs	3.20	5,500.00	17,600.00
d. Reinforcement (Y_{10})	Ctw	9.29	3,300.00	30,657.00
e. 1:2:4: (¾") R. C.Concrete	Cube	1.64	19,000.00	31,160.00
f. Smooth Cement Plaster (including water proof work)	Sqrs	2.45	2,500.00	6,125.00

Appendix 4.4

Details on pumps, aerators, control panel , electric work and plumbing work of the Parakaduwa Rubber Factory.

1. Cost for pumps & aerators:

***Note :**

Additional one unit from each model of pumps and aerators has quoted herewith as standby unit.

Pump (P1) for collection tank

Pump – Centric type NCS 300/4 – 3			-	02 Nos.
(4 HP, Three phase, 400v, 50 HZ, 3" dia.)				
Cost	-	Rs 62,115/= x 2	=	Rs 124,230/=
		GST 12.5%		= Rs 15,529/=
		NSL 0.5%	=	Rs 702/=
				Rs 140,461/=

Aerators (A1 & A2) for aeration tank

Aerators – Centric type CA 200/3			-	03 Nos.
(2 HP, aerators, 400v, 50 HZ,Three phase)				
Cost	-	Rs 79,500/= x 3	=	Rs 238,500/=
		GST 12.5%		= Rs 29,813/=
		NSL 0.5/=	=	Rs 1,348/=
				Rs 269,661/=

Pump (P2) for settling tank

Pump	-	Centric type, Submersible SVS 200/1		- 02 Nos.
(0.75 HP,230V, 50 HZ)				
Cost	-	Rs 20,484/= x 2	=	Rs 40,968/=
		GST 12.5%		= Rs 5,121/=
		NSL 0.5%	=	Rs 232/=
	Control Box (02 Nos.)	Rs 3,200/= x 2	=	Rs 6,400/=
		GST 12.5%	=	Rs 800/=
				Rs 53,521/=

2. Cost for Control panel & Electrical Work

Wiring for the pump at the CT, two aerators, sludge recirculation pump & three Nos. of electric bulbs

No. of wiring points	-	**07**
Cost for wiring (labour + material)	-	07 x Rs 1,400/=
	=	Rs 9,800/=

Estimate for Control panel for pumps & aerators (including timer)

Material cost only

The panel consists of following items.

For P1	02 Nos.	MCB 16A 3 Pole type 3.
	02 Nos.	Starter 4 H.P.
	01 No.	24 hr Timer
	01 No.	1 Off 2 Selector
	02 Nos.	10A 2 pole MCB
For P2	02 Nos.	0.75 H.P. 1 phase Starter
	01 No.	24 hr Timer
	01 No.	5 minute Timer
	01 No.	1 off / 2 Selector
	02 No.	Relays
For A1, A2	02 Nos.	6A 3 Pole MCB
	02 Nos.	2 H.P. Starter
	02 Nos.	24 hr Timer
	02 Nos.	On / Off Selector
	15 Nos.	Indicators
	02 Nos.	Submersible type float switch
	01 No.	PFR
	01 No.	40A 4 Pole ELCB
	01 No.	Steel Enclosure 600 x 800 x 200mm

		Rs 150,333.00
Add GST 12.5%		Rs 18,792.00
Add NSL 0.5%		Rs 850.00
Total material cost for Control panel	-	Rs 169,975.00
Labour cost	-	Rs 50,000.00
TOTAL	-	Rs 204,775.00

Appendix 4.5

Unit Cost Calculations

Using the annuity factors ($A_{r,n}$) convert the Capital cost into annual equivalent cost (AEC).

Capital Investment Cost I ie (A+B) is multiplied by $A_{r,n}$, where r is the interest rate and n in the number of years (period) of depreciation of the Treatment plant

$$AEC=(A_{r,n}) \times I.$$

Annuity factors as function of interest rate and life time

n \ r%	2	4	6	8	10	12	14	16
1	1.0200	1.0400	1.0600	1.0800	1.1000	1.1200	1.1400	1.1600
2	0.5151	0.5302	0.5454	0.5608	0.5762	0.5917	0.6073	0.6230
3	0.3468	0.3604	0.3741	0.3880	0.4021	0.4163	0.4307	0.4453
4	0.2626	0.2755	0.2886	0.3019	0.3155	0.3292	0.3432	0.3574
5	0.2122	0.2246	0.2374	0.2505	0.2638	0.2774	0.2913	0.3045
6	0.1785	0.1908	0.2034	0.2163	0.2296	0.2432	0.2572	0.2714
7	0.1545	0.1666	0.1791	0.1921	0.2054	0.2191	0.2332	0.2476
8	0.1365	0.1485	0.1610	0.1740	0.1874	0.2013	0.2156	0.2302
9	0.1225	0.1345	0.1470	0.1601	0.1736	0.1877	0.2022	0.2171
10	0.1113	0.1233	0.1359	0.1490	0.1628	0.1770	0.1917	0.2069
12	0.0946	0.1066	0.1193	0.1327	0.1468	0.1614	0.1767	0.1924
15	0.0778	0.0899	0.1030	0.1168	0.1315	0.1468	0.1628	0.1794
20	0.0612	0.0736	0.0872	0.1019	0.1175	0.1339	0.1510	0.1687
25	0.0512	0.0640	0.0782	0.0937	0.1102	0.1275	0.1455	0.1640
30	0.0447	0.0578	0.0727	0.0888	0.1061	0.1241	0.1428	0.1619