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Treatment of organic waste from animal slaughteries (plant: Reime Econ)

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Scope:

Reime Econ's physical – biological plant for treatment of organic waste was examined at Vest-Ro's animal slaughtery in Sandeid, SW Norway. The system comprises 1) an initial separation of the waste into a solid and a liquid phase, and 2) a combined solid settling and aerobic biological treatment of the liquid phase. The solid phase is further processed by composting, while the treated fluid phase is led to the domestic sewer system. The gradual and overall treatment efficiency of the plant was estimated by monitoring of the mass flux through the system. An overall reduction of 91 % through the plant was found for Dry matter. With regard to Chemical oxygen demand, Nitrogen and Phosphorus of the liquid phase, the removal efficiency was 85 %, 67 % and 63 %, respectively.

The overall treatment efficiency of Dry matter increased with increasing waste loading up to 1,300 kg DM/day. The Bioreactor of the plant was overloaded in the test. However, the capacity can been adjusted in order to achieve an improved treatment efficiency of organic mater (COD). The total fixed and variable costs of the plant was estimated to NOK 185,000 annually ($US 20,000). Assuming an annual waste loading of 1,500 cu. m of solids and 3,500 cu. m of liquid waste at Vest-Ro, the total treatment costs corresponded to NOK 37 per cu. m ($US 4/cu. m).

Key-words:

Animal slaughtery waste, separation, settling, biological treatment, Reime Econ

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Summary

The efficiency of Reime Econ's pilot plant for treatment of manure, paunch manure and wash water from Vest-Ro's animal slaughtery was assessed. As a first step, the waste is divided into two phases, a solid and a liquid phase, in a Reime Separator. In a combined physical – biological system (primary settling – aerated submerged biofiltration – secondary settling), the liquid fraction is further treated before entering the public sewer system.

Based on monitoring of mass flux, 91 % of the total loading of Dry matter (TDM) was removed through the plant. Most of it (TDM) was removed in the separator. For the liquid fraction from the separator, the following average treatment efficiency was found: 85 % for Chemical oxygen demand (COD), 76 % for Nitrogen (TN) and 63 % for Phosphorus (TP). The treated effluent still contained relatively high concentrations of organic matter and nutrients, or 5 – 10 times the average concentrations of untreated domestic wastewater. However, the content of suspended solids (TSS) of treated effluent was rather low, ca. 0.7 g/L, and similar to the solid content of domestic wastewater. The low solid content confirms a very high efficiency of the physical treatment units of the plant, separation succeeded by a two-step settling.

In the Separator, significantly improved efficiency was demonstrated at increased TDM loading. Obviously, these findings indicate that the capacity of Separator was not fully utilised in the tests. The removal efficiency of TDM in the primary settling tank and of organic matter (COD) in the Reime Bioreactor remained constant within the tested loading range at about 40 % and 48 %, respectively.

The designed organic loading of the Bioreactor was however overloaded by about five times in the tests. Therefore, the found removal in the Bioreactor (average 48 %) was both due to settling of solids and biological degradation. The capacity of the Bioreactor can, however, be adjusted in order to increase the removal efficiency of COD up to at least 80 %.

The total capital and variable costs of the Reime Econ's plant is estimated to NOK 185,000 annually ($US 20,000). At the regarded slaughtery in Sandeid, the total specific treatment costs corresponded to NOK 37 per cu. m ($US 4) assuming an annual waste volume of 5000 cu. m.

Preface

This report describes tests of Reime Econ's plant for treatment of manure, paunch manure and wash water from animal slaughteries. Assessments of monitored mass flux through the system, the efficiency of the single process and the operating economy are presented.

The pilot plant was installed at Vest-Ro's animal slaughtery situated in Sandeid in the northern part of the county Rogaland. All the sampling and monitoring was carried out by Reime Econ (E. Hagman) jointly with the staff at the slaughtery. The water quality analyses were performed at the Environmental Laboratory, Rogaland Research.

The project was financially supported NOK 170,000 by The Norwegian Research Board (program: NORMIL 2000). At Reime Econ, the project managers were E. Hagman and B. Salte. A. Bergheim has been the project manager at Rogaland Research.

1 Approach – objective

At Norwegian animal slaughteries, the annual total volume produced of paunch manure, intestine manure, urine and sawdust amounts to about 50,000 cu. m. Of this, ca. 50 % is paunch manure. The single slaughthery produces 1,000 – 3,000 cu. m organic per year. This waste represents both a local source of water pollution and a resource if utilised as organic manure or compost substrate.

The conditions at five slaughteries in Southern Norway were assessed in a former report (Bergheim *et al.* 1996). Generally, the existing methods for waste management and disposal were temporarily: solid wastes such as manure, paunch content and sawdust were delivered to public land fills or spread on agricultural land, while the liquid wastes (wash water, urine, manure residues) were led to the public sewer. The high organic content of the liquid fraction produced from separation was considered a significant pollution problem. According to Toresen (1993) the liquid waste represents about 270 L per ton of meat produced, or in terms of population equivalents, discharge from 60 – 100 persons for organic matter and nitrogen, and from about 260 persons for phosphorus. Due to public taxes, discharge of untreated fluid waste to the public sewer means a serious extra cost item for the slaughtery.

In Reime Econ's (RE) treatment plant at Vest-Ro's slaughtery, the organic waste (mainly manure, paunch content and wash water) is separated into two fractions in a Reime Separator. The solid fraction is delivered for dry composting at a local farmer. The liquid fraction is further treated in a physical-biological system comprising the following main units: Primary settling tank – Bioreactor (aerobe submerged biofilter) – Secondary settling tank.

Initially, the efficiency of RE's plant was estimated by means of water sampling (Bergheim & Hagman, 1998). The removal rates found were the following: 75 % for TDM, 85 % for TVM (total volatile matter), 80 % for COD, 78 % for BOD_7, 64 % for TP and 68 % for TN. A major part of the removal of organic matter and nutrients took place post-separation, i.e. in the physical-biological system.

Single water sampling will not explain the treatment efficiency properly. In order to develop mass-balance analyses, combined water sampling and flow monitoring was carried out during the follow-up project phase. Monitoring of input factors, such as usage of electricity and air, is highly significant. Another objectives were assessment and optimisation of the single treatment unit and to achieve a budget estimate of the plant.

The designed plant was based on well-known process technology, but no available literature describing a similar system for treatment of slaughtery waste was detected.

2 Material and methods

2.1 Reime Econ's plant

Reime Econ (RE) has developed a plant for treatment of organic wastes, manure and paunch content, in animal slaughteries. The treatment concept was realised closely co-operating with the slaughtery industry. Due to high flexibility, the plant is adaptable to different existing waste systems at the slaughteries. All slaughtery waste flow containing manure, from transport and storage of living animals and from the processing department, are treated by the plant.

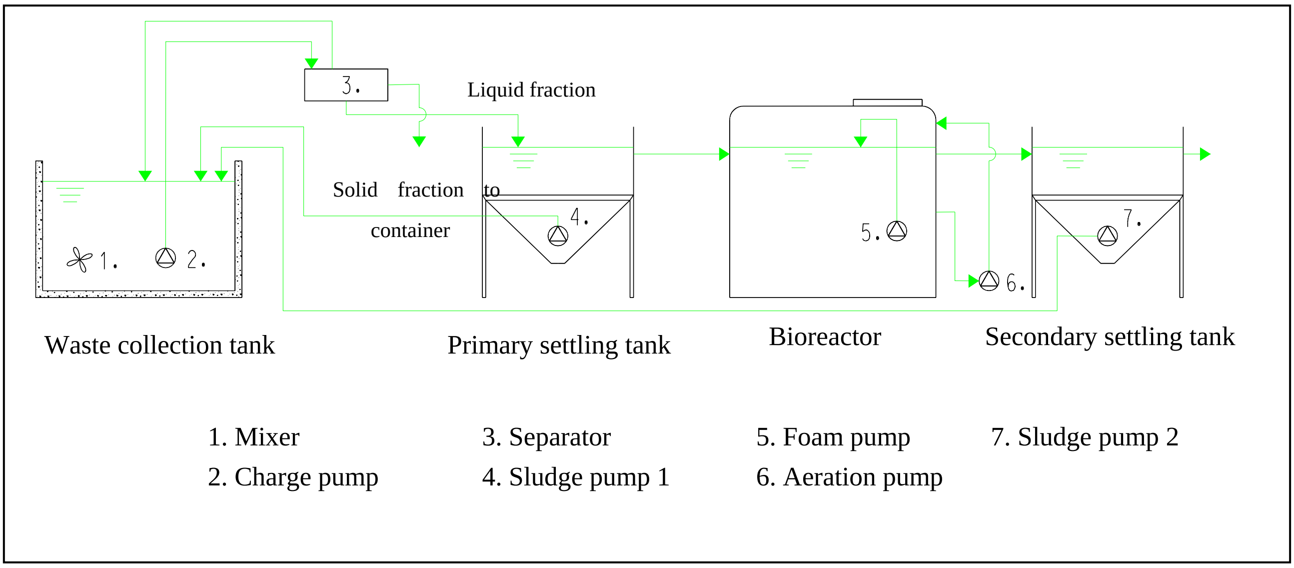

Figure 1. Flow diagram of Reime Econ's waste treatment plant for slaughteries.

The manure containing wastes are led to the Waste collection tank (Figure 1) equipped with a Mixer (1) and a Charge pump (2). The mixed manure is pumped to the Separator (3) for separation into a solid and liquid fraction. A container receives the solid fraction where it is evenly loaded by means of a distribution screw.

Prior separation, the mixture contains between 1,5 and 3 % dry matter (DM), depending on the volume of wash water used. On average, the dry matter content of the solid fraction from the Separator is ca. 30 %, while the liquid fraction contains 0.5 – 1.5 % DM. The weight ratio post-separation is about 75 – 95 % for the liquid fraction and 5 – 25 % for the solid fraction.

Separated solids from the plant are suitable as substrate for composting, solely or mixed with other organic wastes. After storage of 24 hrs in the container, the temperature of the substrate rises to more than 70 ºC.

The liquid fraction is further treated in a physical-biological system:

In the Primary settling tank, larger particles will be removed by settling. Decanting water then moves to the Bioreactor, a submerged aerated biofilter, where the manure liquid is mineralised. The culture of aerobic microorganisms is supported dispersed air from an ejector. The filter medium of the Bioreactor has a specific surface area of more than 100 sq. m/cu. m (m^2/m^3) and has a designed capacity of 17 – 34 g COD/sq. m/day. From the Bioreactor the liquid is led to the Secondary settling tank where the biomass produced in the reactor is removed. Finally, the treated liquid runs to the main outlet from the slaughtery.

Produced sludge is regularly returned to, and mixed with, the slurry in the Waste collecting tank. The sludge is then removed from the system along with the solid fraction from the separator. There is no need for a further processing of raw sludge in the plant. The plant is all-automatic managed from a control system.

2.2 Vest-Ro's animal slaughtery and RE's plant

A complete RE's plant for waste treatment was installed at Vest-Ro's slaughtery in spring 1997. All reported results are obtained at this plant.

Annually the slaughtery produces ca. 1,500 cu. m of intestinal and paunch manure and sawdust. Before 1997, the waste was stored in the slaughtery's yard for direct application on agricultural land. Leachate from the yard constituted to 100 – 200 cu. m annually which was collected in a tank for land application with the solid waste. Vest-Ro purchased the treatment plant to simplify the waste handling. The meat processing industry also expected stricter governmental regulations for land application of untreated waste.

The installed plant treats the described amount of organic wastes plus wash water from animal transport. 15 – 40 cu. m of waste are treated daily. The seasonal waste loading is maximised during the sheep slaughter season in September – October. By 1998, the solid waste from the separator was delivered to the land fill at Toraneset, but other less expensive solutions were considered.

In the treatment plant, the dimensions of the two settling tanks are similar with a surface area of 3.8 sq. m and a volume of 4.0 cu. m. The diameter of the Bioreactor is 3.0 m, the volume is 15 cu. m.

2.3 Monitoring of operational factors

All monitoring and the resulting calculations were carried out on a daily basis (24 hrs). In the period August – October 1998, sampling were conducted on three days (19. Aug., 2 Sep., 1 Oct.). Besides water sampling, the following operational factors were included:

Quantification of solids

Produced solids from the Separator was collected and weighed during 24 hrs. In addition, a representative sample for monitoring of Total dry matter (TDM) was taken. The daily produced quantity of dry matter was calculated by the function:

TDM (kg/day) = Solids (kg w.w./day) x TDM (g/kg)

Monitoring of flow

Prior to sampling, the water level of the Primary settling tank was reduced and the time (Δt) to refill the volume (ΔV) was noted. By this simple procedure the flow capacity of the Separator was calculated: Flow (cu. m/day) = $\Delta V/\Delta t$ x T, where T is the operational time of the Separator per day.

Monitoring of air

The air velocity (v) from the ejector was monitored by means of a velocity meter (type: Testo 415). Thus, the air flow to the Bioreactor was calculated: Air flow (cu. m/min) = v x A, where A is area of the air pipe.

Monitoring of electricity

An electric meter was installed at the inlet of the control box. The average daily power consumption was found by reading during selected periods.

2.4 Water sampling and analyses

The three daily samplings were on 19 August, 2 September and 1 October.

Five sampling sites were included:

1 Waste collection tank

2 Outlet Separator (inlet Primary settling tank)

3 Outlet Primary settling tank (inlet Bioreactor)

4 Outlet Bioreactor (inlet Secondary settling tank)

5 Outlet Secondary settling tank (to recipient)

At site 2 (outlet Separator), 3 samples each of 1 L were collected during 3 hours, mixed and 1 L composite sample was brought to the laboratory. From sites 3, 4 and 5, 10 L sample volume was collected from the outlet pipes (3 hrs.), of which 1 L composite sample was analysed. Due to problems of getting representative samples directly from the Waste collection tank (1), the concentrations had to be *calculated* based on the monitored mass fluxes of solid and liquid waste from the Separator.

The samples were at once brought to the Laboratory, Rogaland Research. In the Laboratory, sub-samples were collected for monitoring of Total dry matter (TDM). Filtration of the samples (glass fibre filter, 0.45 µm) was impossible because of the high solid content. Consequently, the samples were pre-treated by decanting in order to approximately determine solid and liquid based fractions of Chemical oxygen demand (COD):

COD total = sub-sample of whole sample (before decanting)
COD decanted = sub-sample of decanted fraction after 24 hrs of settling
COD settleable = COD total – COD decanted

At one sampling, 2 September, analysis of Total nitrogen (TN) and Total phosphorus (TP) were carried out. With the exception of the mentioned pre-treatment procedure, all treatment and analytical procedure were performed in accordance to Norwegian Standards.

Calculations:

Flux (F) = C_i x Q_i, where *C* is concentration, *Q* is flow and *i* is sampling site (1 – 5). Unit: kg/day (24 hrs)

Treatment efficiency (TE) = $[(F_i - F_{i-1})/F_i]$ x 100, where *F* is flux. Unit: %

3 Results and comments

3.1 Mass flux and system efficiency

The average mass flux through the plant, based on calculations described in Appendix, is presented in Figure 2. Figure 3 shows the treatment efficiencies in percentage. With regard to TDM, the flux is calculated through the whole system (from Waste collection tank to the final outlet), while the flux of the other parameters includes the physical-biological part of the plant (from Separator to the outlet).

Of total TDM, about 69 % were removed in the Separator and further about 21 % in the physical-biological part (totally 91 % removed). Consequently, more than two thirds of the dry matter from the slaughtery consisted of larger solids (sawdust, manure particles) suitable for mechanical removal. Organic matter, as COD, was also dominated by solids (COD total >> COD settleable). In the physical-biological unit, COD was reduced by 85 %, TN by 67 % and TP by 63 %. The solid dominated parameters (COD and COD total/COD settleable), were mainly removed in the settling units, while dissolved components (COD decanted, TN and TP) were evenly removed in both the settling units and the Bioreactor (Figure 3).

Despite a high removal efficiency, the treated outlet still represented a considerable loading: 600 – 700 *pe* for COD and TN, and more than 2000 *pe* for TP (*pe*: population equivalent loading factor).

3.2 Process efficiency

The removal efficiency of TDM in the Separator increased significantly with increasing TDM loading (Figure 4). These findings indicate that the capacity of this unit (Separator) was not fully utilised in the tests. In the Primary settling tank, the removal rate of TDM remained constant within the tested loading range at about 40 %. Similarly, a constant removal rate at 48 % was found for organic matter (COD) in the Reime Bioreactor. The hydraulic loading in the tests (27 – 41 cu. m/day) was lower than the designed hydraulic capacity of the plant (48 cu. m/day).

The designed organic loading of the Bioreactor (17 – 34 g COD/sq. m/day) was however overloaded by about five times in the tests (existing loading: 100 – 190 g COD/sq. m/day). Therefore, the found removal in the Bioreactor (average 48 %) was both due to settling of solids and biological degradation. In another test of a similar biofilter, organic components in the effluent from food processing industry were removed at a rate of 80 – 90 % as COD at a specific loading of 12 - 24 COD/sq. m/day (Rusten & Thorvaldsen, 1983). The removal efficiency was reduced to 40 – 42 % when the loading increased to 161 g COD/sq. m/day.

The capacity of the Reime Bioreactor can be adjusted to the capacity of the other units of the plant.

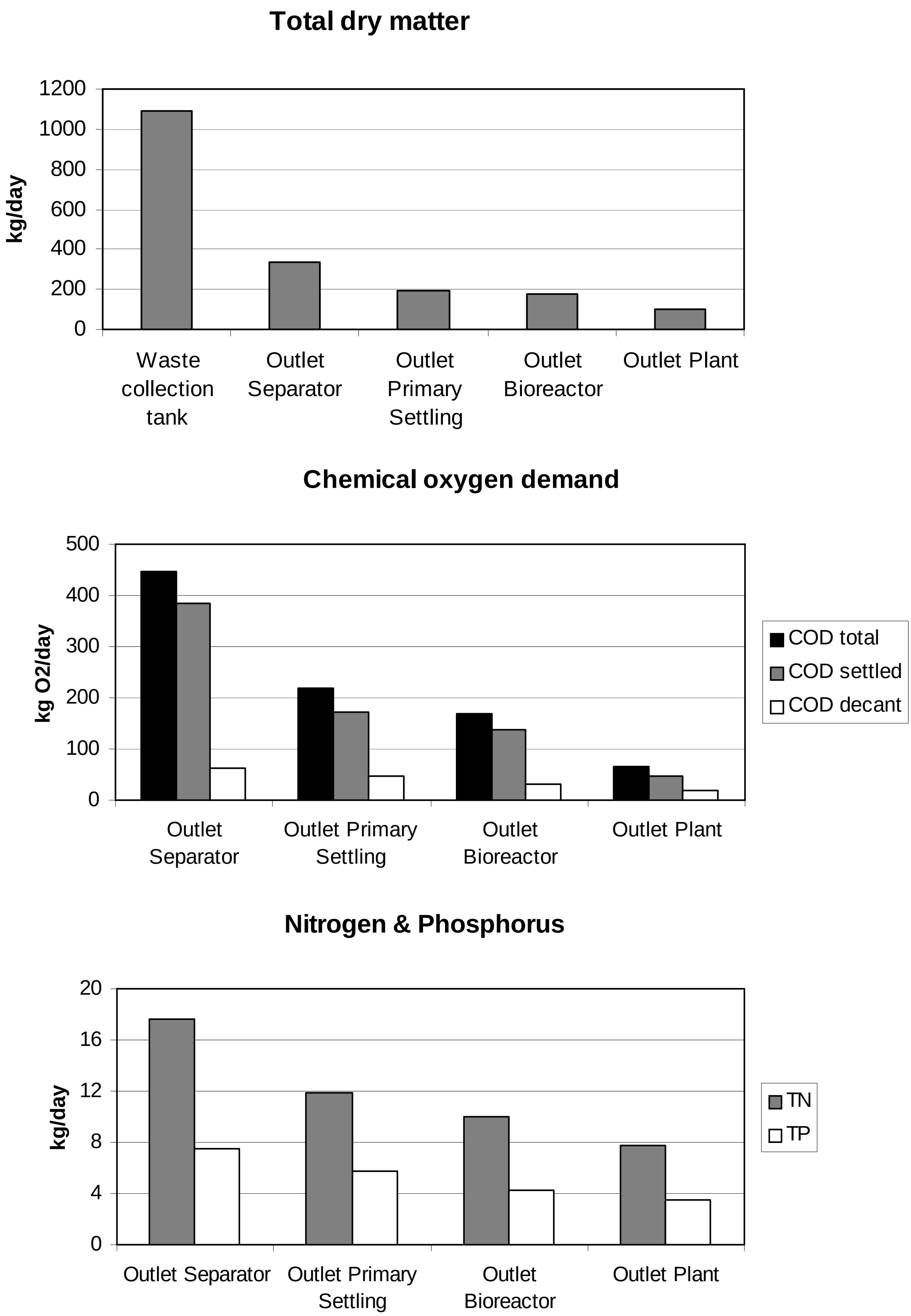

Figure 2. Mass flux through Reime Econ's waste treatment plant at Vest-Ro's animal slaughtery, Sandeid, SW Norway

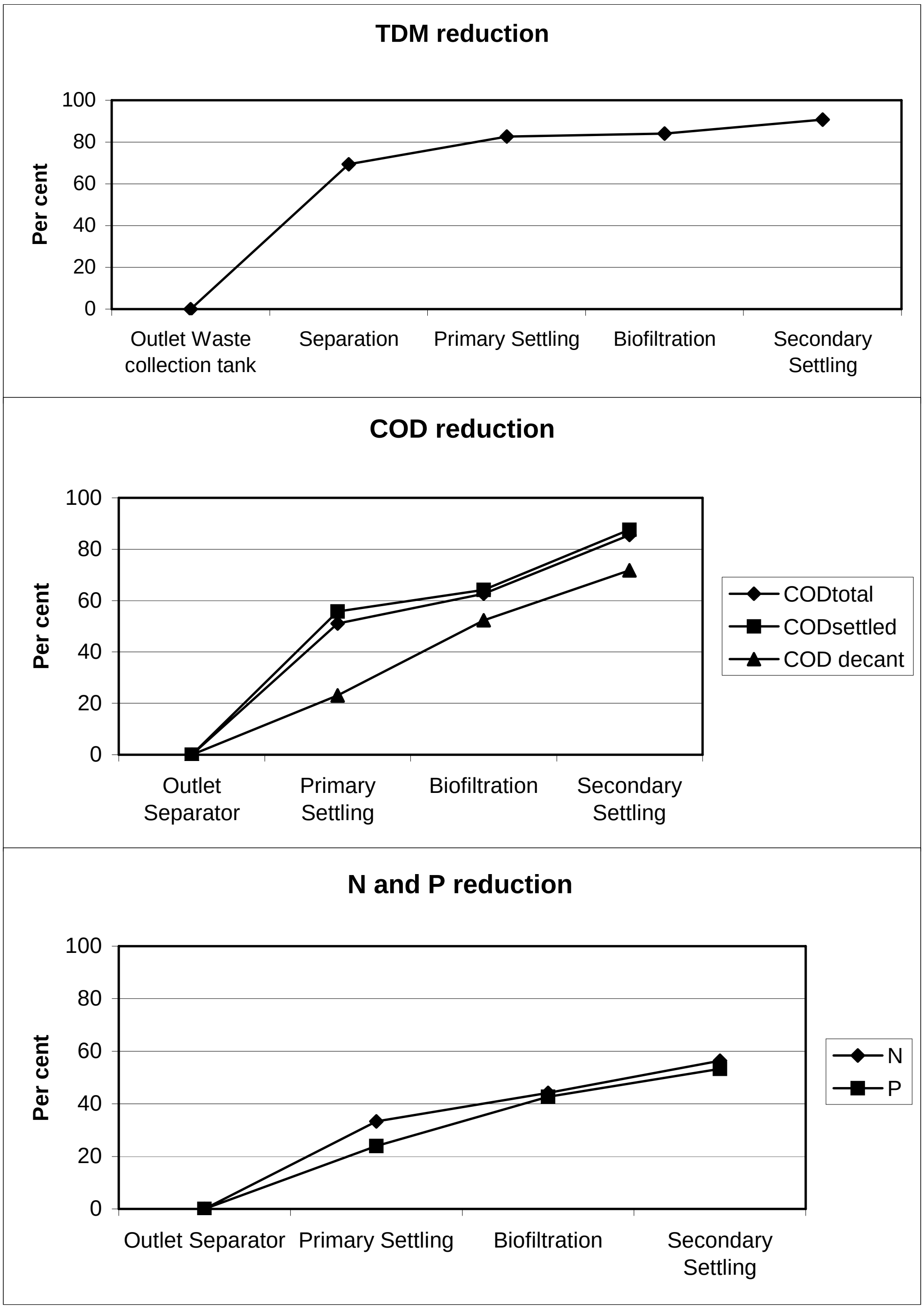

Figure 3. Percentage accumulated treatment efficiency, Reime Econ's waste treatment plant at Vest-Ro's animal slaughtery, Sandeid, SW Norway

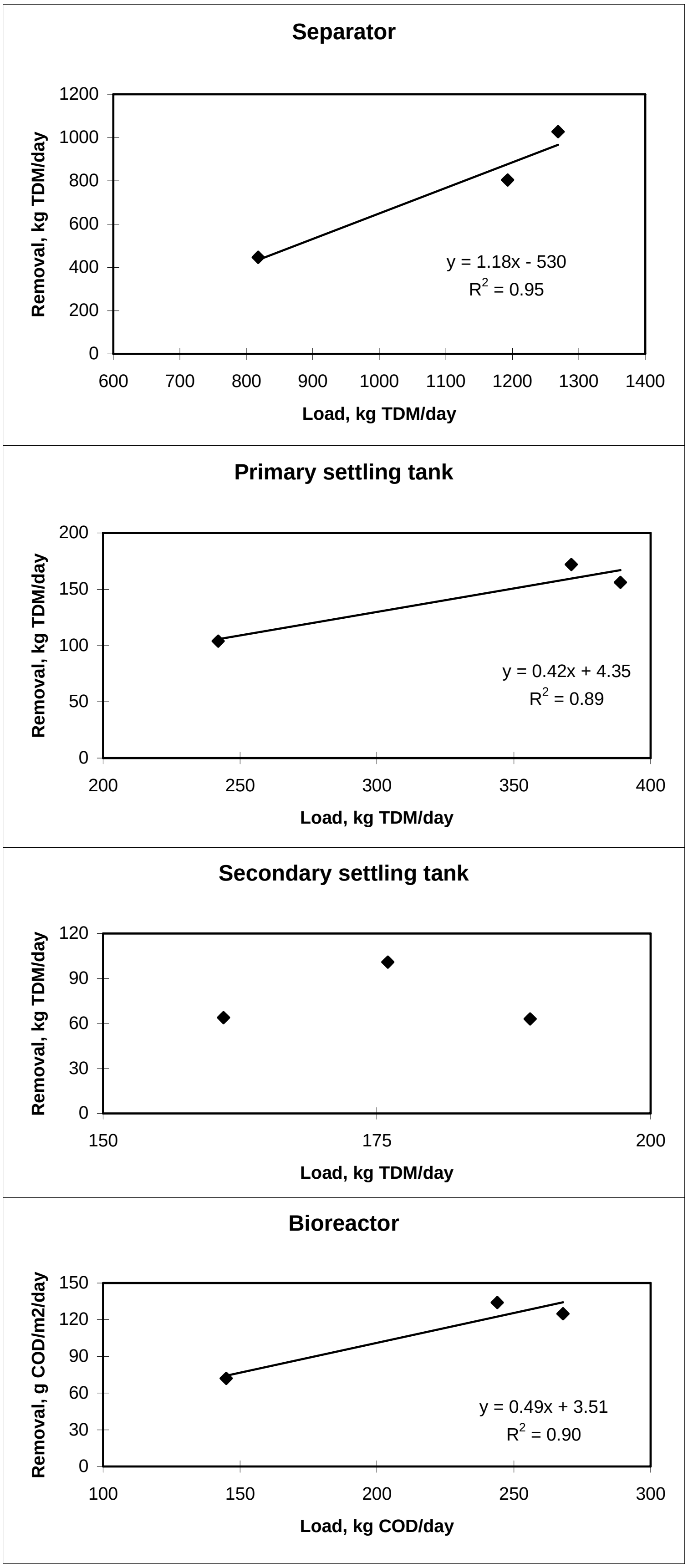

Figure 4. Removal rate at varying waste loading, Reime Econ's waste treatment plant at Vest-Ro's animal slaughtery, Sandeid, SW Norway

3.3 Treatment costs

The calculated capital costs were NOK 122,400 (US$ 14,000) per year assuming 10 years of depreciation and 7 % rate of interest. Annual costs of wages, electricity and purchase of spare parts constituted NOK 62,000 (US$ 7,000) or ca. 30 % of the total costs, NOK 184,400 (US$ 21,000). Including sawdust, paunch content and manure, the total waste volume was ca. 1,500 cu. m per year. Thus, the install and management of the treatment plant correspond to an overall cost of NOK 123 (US$ 14) per cu. m of treated solid waste. The volume of wash water from animal transport, the slaughtery's yard and the paunch rinsing department constitutes however 2 – 3 times the volume of solid wastes. Assuming a total annual flow through the plant of 5,000 cu. m (200 operating days, 25 cu. m/day) leads to an average cost of NOK 37 per cu. m (US$ 4.2).

The total costs of waste treatment and disposal of solids will be doubled if the treated waste is delivered a municipal tip. In other words, considerable amounts might be saved if the wastes are disposed and utilised otherwise.

Table 1. Cost budget of Reime Econ's waste treatment plant at Vest-Ro's slaughtery in Sandeid, SW Norway. Unit: NOK

	Unit	**Nos.**	**Cost/unit**	**Cost/year**
Capital costs:				
Complete plant		1	862,000	
Depreciation (10 years)				86,200
Interest (7 % pa)				36,204
Total capital costs				122,404
Operational costs:				
Disposal solid waste	tons of DM	500	300	150,000
Wages	hrs	230	150	34,500
Spare parts	RS	1	20,000	20,000
Electricity	kwh	25,000	0.3	7,500
Total operational costs				212,000
Total costs per year				334,404

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5 Appendix

Analysis Reime Econ's waste treatment plant at Vest-RO's slaughtery, Sandeid, SW Norway

1: Waste collection tank

2: Outlet Separator, Inlet Primary settling tank

3: Outlet Primary settling tank, Inlet Bioreactor

4: Outlet Bioreactor, Inlet Secondary settling tank

5: Outlet Secondary settling tank, Inlet recipient

Date	TDM, g/L					COD total, mg O/L				
	1	2	3	4	5	1	2	3	4	5
19.08.98	13.6	6.9	4.3	5.5	2.5	15400	10470	4525	6260	1500
02.09.98	-	9.9	6.3	5.1	3.8	-	12120	7280	4400	2620
01.10.98	-	14.0	8.4	6.8	4.3	-	18800	10300	5860	2550

Date	COD decanted, mg O/L					COD settleable, mg O/L				
	1	2	3	4	5	1	2	3	4	5
19.08.98	1780	1690	1200	1590	476	13620	8780	3325	4670	1024
02.09.98	-	2180	1930	555	706	-	9940	5350	3845	1914
01.10.98	-	1563	1438	749	599	-	17237	8862	5111	1951

Date	TN, mg/L					TP, mg/L				
	1	2	3	4	5	1	2	3	4	5
19.08.98	-	-	-	-	-	-	-	-	-	-
02.09.98	-	447	321	270	216	-	190	155	117	98
01.10.98	-	-	-	-	-	-	-	-	-	-

Calculated mass flux

Vest-Ro 19-8-98

Sampling site	TDM, kg/ cu.m	TDM, kg/day	COD tot, kg/day	COD dec., kg/d	COD settl., kg/day	TN, kg/day	TP, kg/day	Q, cu.m/day	Retention period, hrs
Waste collection tank	34.1	1269	2902	66	2836			37.2	
Outlet Separator	6.9	242	368	59	308			35.1	
Outlet Primary settling tank	4.3	138	145	38	107			32.1	3.0
Outlet Secondary settling tank	5.5	176	201	51	150			32.1	3.0
Outlet plant	2.5	75	45	14	31			30.0	12.0

Vest-Ro 02-9-98

Sampling site	TDM, kg/ cu.m	TDM, kg/day	COD tot, kg/day	COD dec., kg/d	COD settl., kg/day	TN, kg/day	TP, kg/day	Q, cu.m/day	Retention period, hrs
Waste collection tank	29.0	1193	4814	91	4723	125	35	41.2	
Outlet Separator	9.85	389	479	86	393	18	8	39.5	
Outlet Primary settling tank	6.33	233	268	71	197	12	6	36.8	2.6
Outlet Secondary settling tank	5.13	189	162	20	142	10	4	36.8	2.6
Outlet plant	3.78	135	94	25	68	8	3	35.7	10.1

Vest-Ro 01-10-98

Sampling site	TDM, kg/ cu.m	TDM, kg/day	COD tot, kg/day	COD dec., kg/d	COD settl., kg/day	TN, kg/day	TP, kg/day	Q, cu.m/day	Retention period, hrs
Waste collection tank	30.0	818	1242	60	1182			27.3	
Outlet Separator	14.0	371	498	41	457			26.5	
Outlet Primary settling tank	8.4	199	244	34	210			23.7	4.0
Outlet Secondary settling tank	6.8	161	139	18	121			23.7	4.0
Outlet plant	4.3	97	57	13	44			22.4	16.0

Average
19-8 – 01-10-98

Sampling site	TDM, kg/ cu.m	TDM, kg/day	COD tot, kg/day	COD dec., kg/d	COD settl., kg/day	TN, kg/day	TP, kg/day	Q, cu.m/day	Retention period, hrs
Waste collection tank	31.0	1093.6	2985.8	72.3	2913.5	125.3	34.8	35.2	
Outlet Separator	10.3	334.1	448.1	62.3	385.9	17.7	7.5	33.7	
Outlet Primary settling tank	6.3	190.1	219.2	47.9	171.3	11.8	5.7	30.9	3.2
Outlet Secondary settling tank	5.8	175.5	167.3	29.7	137.5	9.9	4.3	30.9	3.2
Outlet plant	3.5	102.1	65.2	17.6	47.6	7.7	3.5	29.4	12.7