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Abstract: Treatment of septage is a major problem in many European countries. Most countries in Europe handle the septage by discharging it to the sewer line or at the treatment plant inlet. In Scandinavia septage is quite often discharged directly to the sludge treatment facility at a municipal treatment plant. Operational problems at wastewater treatment plants due to septage addition have often been severe.
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TREATMENT OF SEPTAGE
EUROPEAN PRACTICE

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ABSTRACT

Treatment of septage is a major problem in many European countries. Most countries in Europe handle the septage by discharging it to the sewer line or at the treatment plant inlet. In Scandinavia septage is quite often discharged directly to the sludge treatment facility at a municipal treatment plant. Operational problems at wastewater treatment plants due to septage addition have often been severe.

Specific septage quantities vary considerably between different countries. The same is true regarding the septage characteristics. The specific septage volume recommended for design is 0.4-0.6 m^3 per person and year for pumping intervals less than one year and 0.6-0.8 m^3 per person and year for pumping intervals more than one year. In areas where private companies take care of the pumping and transportation, the maximum daily septage quantities received at the municipal wastewater treatment plant is up to 4.9 times the yearly average quantity.

Septage contains 30-40 l/m^3 septage of screening, grit and sand that have to be removed prior to sludge processing.

The European experience it that septage can be anaerobically -, aerobically and lime-stabilized. Addition of concentrated filtrate or centrate from septage to the wastewater flow at a wastewater treatment plant reduces effluent quality and often causes operational problems. This is especially true at primary-chemical treatment plants.

Handling of septage creates an odor problem that has to be taken seriously. Different odor reduction systems are presently in use at existing treatment plants.

An alternative to septage reception at wastewater treatment plants is mobile dewatering units recently introduced in Scandinavia. There are several potential advantages to such a system; including lower transportation cost and lower additional loading at the wastewater treatment plant.

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SECTION 1

INTRODUCTION

Treatment of septage is a major problem in many European countries. The problem has previously drawn limited attention since it was generally agreed that when sewer systems and treatment facilities were constructed, the problem with septage would disappear. Today it is acknowledged that treatment and disposal of septage is a problem that can be solved only through thorough engineering evaluations. Regulations regarding treatment and disposal have been missing or been too general in nature. Many countries in Europe are therefore in the process of evaluating their septage management procedures.

When looking into the European practice regarding treatment of septage, it becomes apparent that very little communication has taken place between the different countries. Each country or even separate counties within one country have their special methods for treatment and disposal of septage.

Most countries in Europe handle the septage by discharging it to the sewer lines or at a wastewater treatment plant inlet. This is a practical solution if the sewer system and the wastewater treatment plant have the necessary capacity to handle the septage. It is also important that the treatment plant has the necessary unit operations to remove the additional pollutants from the septage.

In countries where many of the treatment plants are either primary or primary-chemical, the septage is usually added to the sludge treatment units at the treatment plant. In Norway, this has been done for several years, but the operational problems due to the septage addition have been severe. In addition, many of the plants receiving septage did not meet effluent requirements. Work was therefore initiated in 1976 to find what caused the problems, and how they could be solved.

In 1981 the United States Environmental Protection Agency (EPA) asked the Norwegian Institute for Water Research (NIVA) to summarize the European information on septage quantities, characteristics, and treatment methods, with an emphasis on the research work in Norway.

At this same time, EPA was sponsoring a similar study of U.S. septage management practices. This effort, by Stearns & Wheler, Engineers and Scientists, to develop a design handbook, became the vehicle by which European information would be published. NIVA became associated consultant to Stearns & Wheler.

In the following sections information is presented on septage quantities, characteristics, and treatment methods. An effort has been made to include as much practical information as possible without excluding important research findings.

SECTION 2

SEPTAGE QUANTITY

GENERAL

It is often pointed out that little is known about septage quantities from septic tanks and its characteristics in respect to solids content, dewaterability, etc. The reason for this is primarily that there was no need to know. The septage was quite often disposed of at sanitary landfills or directly on farmland, and there was usually very little control with the disposal practice.

Discharge of septage into municipal sewers has been common in many countries. This is also true for discharge at the wastewater treatment plant inlet. As the emphasis on treatment plant performance increased, it became evident that the septic tank sludge added to the treatment plant had severe effects on plant performance. The need for information on septic tank sludge quantities and characteristics increased. In Norway and many other countries research has been carried out to fill the gap in knowledge about handling and disposal of septic tank sludges.

SPECIFIC SLUDGE QUANTITIES

The amount of septage from a septic tank will depend on the volume of the tank, how often the tank is emptied, and the procedure used when emptying the tank.

Septage quantities from septic tanks in Norway were investigated in a research project at NIVA during 1973-74 (Paulsrud et al., 1974). Figure 2.1 shows that the median value of septage is 0.35 m^3 per person per year. If all values less than 0.1 m^3 per person per year and more than 1.0 m^3 per person per year were discarded, the mean sludge quantity was found to be 0.4 m^3 per person per year. Løken (1976) points out that it is very difficult to obtain information on tank sizes and how often homeowners empty their tank. These two factors will influence the specific septage quantities generated.

The Norwegian Ministry of Environment requires each homeowner to empty his septic tank at least once a year and tanks at recreational homes once every three years (Miljøverndepartementet, 1980). The authorities do not say if all the three chambers must be emptied or only the first chamber (see Figure 2.2). This will of course have a great bearing on the total sludge quantities which a community will have to take care of. In Norway the State Pollution Control Authority (SFT, 1977) gives a specific septic tank sludge quantity equal to 0.250 m^3 per person per year. This value agrees very well with the Swedish recommended design value of 0.225 m^3 per person per year (SNV, 1974). However, investigations carried out in Sweden (Werner, 1976) have concluded that the

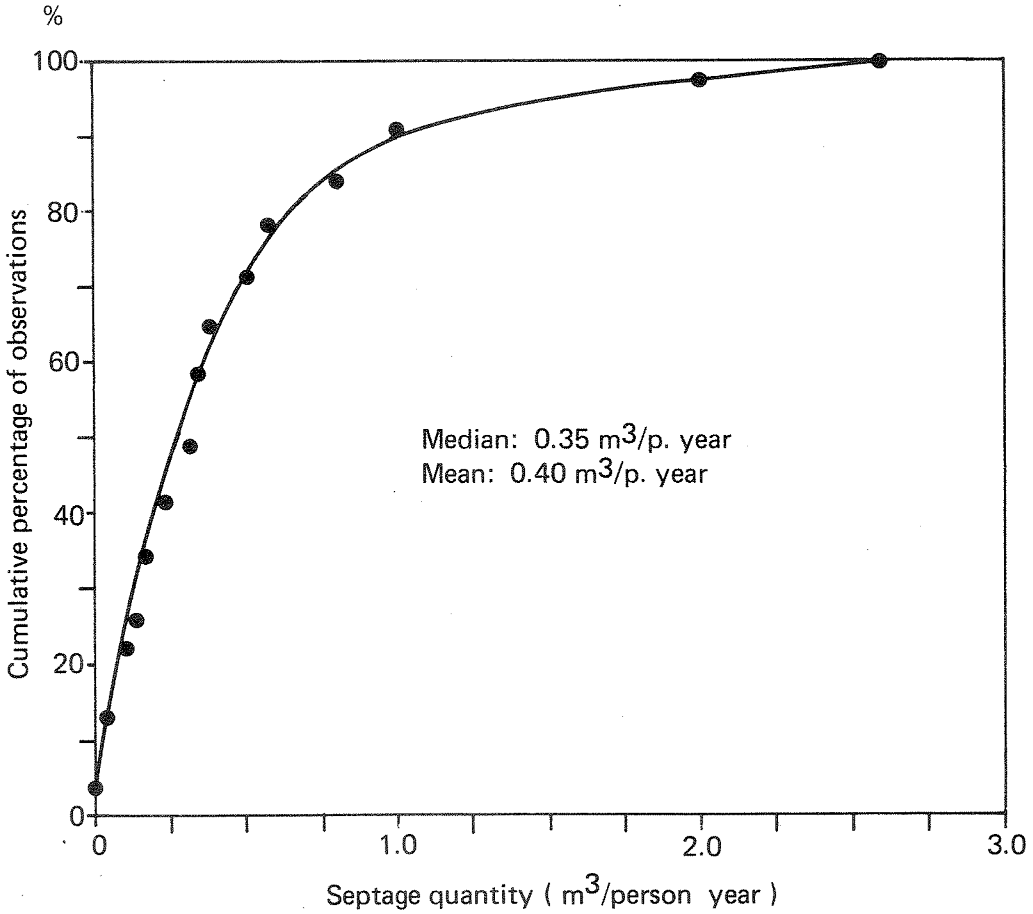
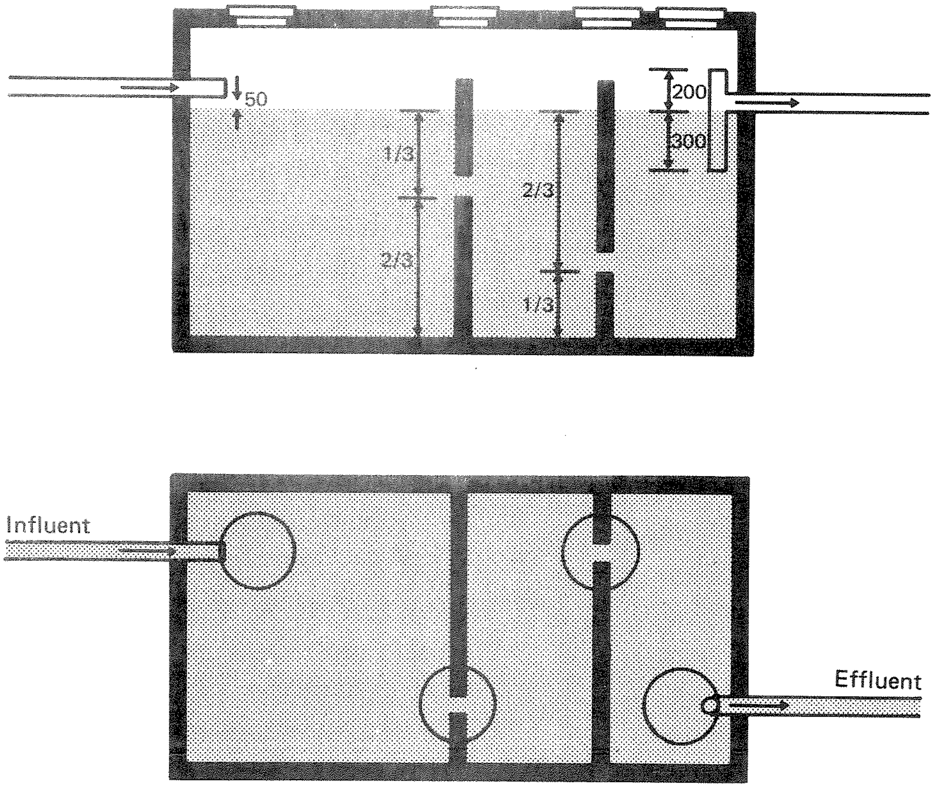


Figure 2.1. Quantity of septage emptied from septic tanks in Norway (Løken, 1976).



(Whole numbers in mm.)

Figure 2.2. Typical septic tank with three chambers.

specific septage quantities are as low as 0.140 m^3 per person per year. Brandis (1978) recommends 0.200 m^3 per person per year as septage accumulation rate for design of treatment and disposal facilities for septage. The actual specific sludge accumulation rates found by Brandis, however, varied between 0.065 and 1.05 m^3 per person per year.

Because very little sludge will accumulate in the second chamber if the tank is cleaned once a year, the general practice should be to clean only the first chamber once a year, and not the second and the third chamber. This will reduce the overall sludge quantities that have to be taken care of by the community.

German guidelines (ATV-Regelverk, 1974) give the specific septic tank sludge quantity as 1.0 m^3 per person per year. The value is given without any comments to how often the tank is emptied, but it is based on a tank volume of 4 m^3. Sludge quantities deviating greatly from the value given in ATV guidelines must therefore be expected. A survey carried out in Germany (Resch, 1979) indicates this; this is shown in Table 2.1.

TABLE 2.1. SEPTAGE QUANTITIES IN WEST GERMANY IN 1977 (Resch, 1979)

State	Inhabitants x 1000	No of septic tanks x 1000	Person per tank	Septage quantities	
				1000 m^3/yr	m^3/person.yr
Baden-Württemberg	822	160	5.1	800	0.97
Bayern	2305	535	4.3	1960	0.85
Berlin (West)	58	13	4.7	100	1.72
Bremen	40	8	5.0	40	(1.00)
Hamburg	136	40	3.4	600	4.38
Hessen	1108	300	3.7	1500	1.35
Niedersachsen	1214	400	3.0	700	0.58
Nordrhein-Westfalen	2130	425	5.0	2130	(1.00)
Rheinland-Pfalz	900	180	5.0	900	(1.00)
Saarland	540	140	3.9	60	0.11
Schleswig-Holstein	545	135	4.0	550	(1.00)
	9798	2336	4.2	9340	0.95

( ) = ATV value.

The values vary between 0.11 and 4.38 m^3 per person per year. The frequency of cleaning the septic tanks in the study by Resch was as follows:

every 4 year	ca. 1 percent of the septic tanks
" 2 year	ca. 34 percent " " " "
" 1 year	ca. 25 percent " " " "
On request from the homeowner	ca. 40 percent " " "

There is reason to believe that the great difference in the time between each cleaning is the major reason for the wide variations in the specific septage quantities.

A study in Västernorrland's county in Sweden (K-Konsult, 1978) revealed specific septage quantities from septic tanks that varied between 0.37 and 1.28 m^3 per person per year (see Table 2.2). Again the wide variation in specific quantities is due to different tank volumes, practical routines regarding emptying the tanks, etc.

TABLE 2.2. SPECIFIC SEPTAGE VOLUME IN VÄSTERNORRLAND's COUNTY, SWEDEN (K-Konsult, 1978)

Area	Population served by septic tanks	Septage volume m^3/yr	Specific sludge volume $m^3/person.yr$
Sundsvall	8940	4700	0.53
Timrå	1700	2175	1.28
Ånge	4800	4000	0.83
Härnösand	2500	1900	0.76
Kramfors	2700	-	-
Sollefteå	5892	6985	1.19
Örnsköldsvik	4221	1550	0.37

SPECIFIC SLUDGE VOLUMES FROM HOLDING TANKS FOR TOILET WASTE

In many European countries the use of a holding tank for toilet waste is quite common. This sludge is usually disposed of in the same way as ordinary septic tank sludge, but the volumes produced and the characteristics of the waste will be different from ordinary septic tank sludge.

Very limited information is available regarding the volumes of septage produced in these holding tanks. The volume will depend on

1. The amount of feces and urine discharged to the tank
2. The flushing volume for the toilets used
3. The usage of the toilets.

An adult produces approximately 1.6 litre of feces and urine per day (Guttormsen et al., 1978). Today toilets with quite low water consumption are marketed (0.8-3.0 l/flush). The number of flushes per person per day will vary, but 4 times a day is suggested as an average value (Paulsrud, 1980). In this study on treatment of septage from closed systems he estimated the volume to be from 1.7 to 4.9 m^3/p.yr, with an average value of 3.0 m^3/p.yr.

VARIATIONS IN SLUDGE QUANTITIES RECEIVED AT MUNICIPAL TREATMENT PLANTS

The design of wastewater treatment plants with receiving facilities for septage is quite often based on an average estimated septage quantity. Very few municipalities have a good record of the amount of septage disposed of in a district. The "normal" procedure in estimating the total sludge quantity is to use a specific quantity per person per year and multiply by the number of inhabitants connected to septic tanks. Very little effort was usually made to find out if the specific sludge quantity used was correct. The result was very often severe overloading of the plants (Medbø, 1975). Also very little information was available regarding the characteristics (BOD, COD, etc.) of the septic tank sludge and the sludge liquor after various types of treatment. Plants with the necessary hydraulic capacity were often subject to organic overloading.

In Scandinavia private firms usually pump the tanks and haul the sludge to the receiving facilities. Most of these firms keep a record of the quantities of sludge hauled in a given period of time. These data must be used with caution since they are often collected for tax purposes and not as a basis for design.

In order to find variations in "flow" of septage to municipal treatment plants the daily quantities received at four municipal treatment plants in Norway with facilities for handling septage were recorded. The investigation was carried out for 3 years at Brumunddal Treatment Plant, for 2 years at Enga Treatment Plant, and for one year at Lillehammer and Heistad Treatment Plants. The result is illustrated in Figures 2.3-2.6.

Since past experience clearly indicated that the calculated volumes of septage based on a specific septic tank sludge volume were inadequate for design purposes, the "peak" factors had to be determined through actual observations at existing plants. Table 2.3 gives a summary of the result. The monthly volume received in late fall was more than twice the average monthly volume. The maximum daily volume of septage was almost 5 times the average daily volume based on one year's observations.

The observations made at the different treatment plants regarding the volumes of septage also gave valuable information regarding the private septic companies. They seem to have the highest activity in September to November. This is in many instances the period of the highest hydraulic loadings at municipal treatment plants, and thus the "internal" sludge production is at its maximum.

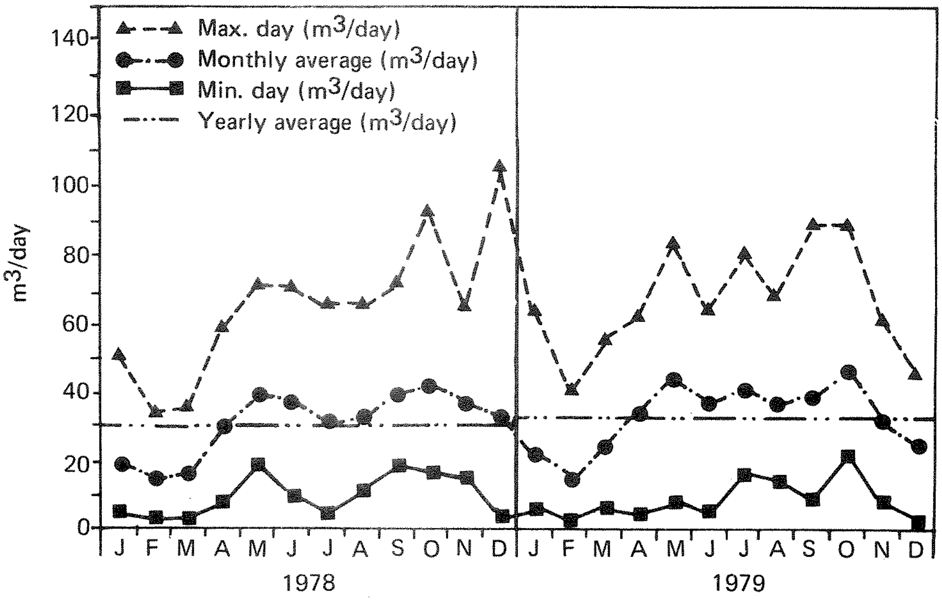


Figure 2.3 Volume of septage received at Enga Treatment plant, Norway (Eikum, 1980).

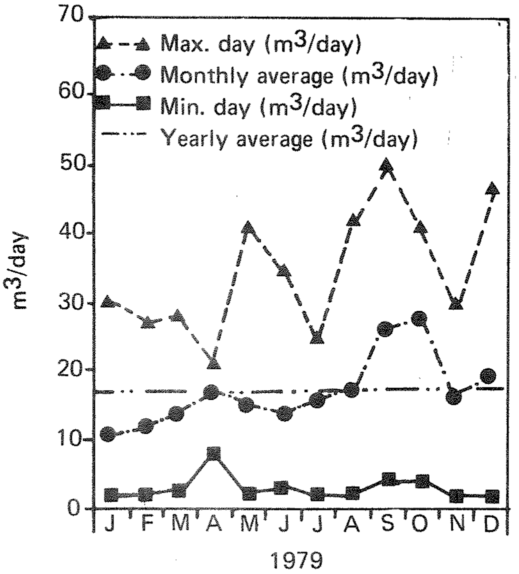


Figure 2.4 Volume of septage received at Heistad Treatment plant, Norway (Eikum, 1980).

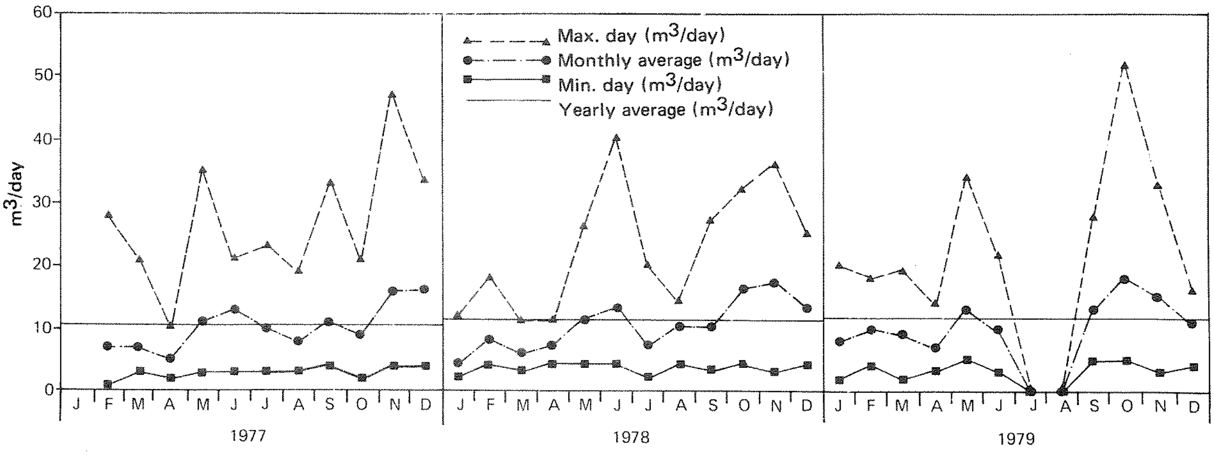


Figure 2.5 Volume of septage received at Brumunddal Treatment Plant, Norway (Eikum, 1980).

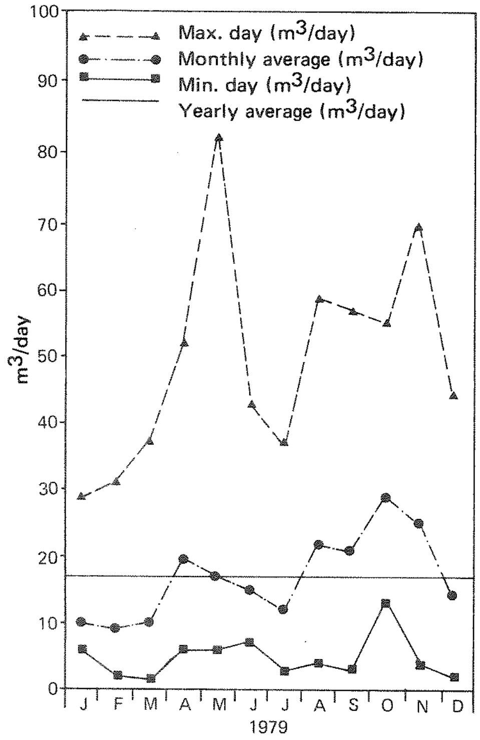


Figure 2.6 Volume of septage received at Lillehammer Treatment Plant, Norway (Eikum, 1980).

TABLE 2.3 VARIATIONS OF SEPTAGE VOLUMES RECEIVED AT FOUR MUNICIPAL TREATMENT PLANTS IN NORWAY

Treatment plant	Year	$K_{1\ max}$	$K_{2\ max}$	$K_{3\ max}$	Comments
Enga	1978	1.42	3.12	3.42	
-"-	1979	1.57	2.91	2.73	$K_1 = \frac{\text{Monthly volume (m}^3\text{/month)}}{\text{Monthly aver. (m}^3\text{/month)}}$
Heistad	1979	1.73	2.73	2.94	
Brumunddal	1977	1.93	4.0	4.42	$K_2 = \frac{\text{Max. day (m}^3\text{/day)}}{\text{Average day (m}^3\text{/day)}}$
-"-	1978	2.14	3.08	3.70	
-"-	1979	2.22	2.89	4.52	$K_3 = \frac{\text{Max. day (m}^3\text{/day)}}{\text{Yearly aver. (m}^3\text{/day)}}$
Lillehammer	1979	1.88	4.88	4.88	

Previously in Scandinavia very few septic tanks were emptied in the winter. Only tanks with clogging problems were taken care of. From the observations made in the last 5 years in Norway, one can conclude that as soon as adequate receiving facilities are constructed, the pumping will take place all year although the volumes are lower in the winter period.

In all the four areas discussed above, there are private companies taking care of the septic tank pumping and sludge transport to the receiving facilities. In communities where this is a public service, it is easier to control the number of truckloads per day. Our experience in Norway, however, indicates that you still have wide variations in the septage volume during the year.

ESTIMATING SEPTAGE VOLUMES FOR THE DESIGN OF RECEIVING FACILITIES

It is of utmost importance to properly estimate the volume of septage to be handled; regardless of how well the design of each unit process is known, it is of limited value unless the total septage quantity to be handled is estimated accurately.

The design criteria for the different units' operations will not be discussed in this section, but rather the specific sludge volumes recommended to be used in calculating the total volume of sludge.

As mentioned previously, the specific septage volumes will depend on numerous factors like tank volume, how often the tank is emptied, etc. In the literature these factors are usually not well documented. It is therefore very difficult to arrive at definite conclusions regarding a specific septage volume.

The following recommendations are based on the research on this subject undertaken in Norway plus the information available from Germany and Sweden.

TABLE 2.4 RECOMMENDED SEPTAGE QUANTITIES

	Cleaning interval	Specific septage volume (m^3/p.yr.)
Septic tank	> 1 year	0.4 - 0.6
" "	< 1 year	0.6 - 0.8
Holding tank	-	3.0

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SECTION 3

UNTREATED SEPTAGE CHARACTERISTICS

In general there is much information available on septage characteristics, compared to the amount of data available on specific sludge quantities. However, considering the difficulties in taking representative samples and acknowledging the factors influencing the septage quality (septic tank volume, pumping procedure, sampling procedure, etc.), there is reason to expect a wide variation in the values given for the different parameters. It is important from a design standpoint to be aware of this before using literature data in actual treatment plant design.

SCREENINGS. GRIT AND SAND QUANTITIES

Septage contains large solids and trash that should be removed before undergoing further treatment. The quantity of this material generated will largely depend upon the amount in the raw septage and the efficiency of the preliminary treatment.

At many treatment plants the screenings, the grit and the sand are discharged into the same container for final disposal. Figures given on the volumes of this material will therefore often be the total volume from the pretreatment units.

Grit and sand from a separate grit chamber handling septage will at times be pumped to the grit chamber for the wastewater entering the treatment plant (see section 4). The reason for this is to reduce the organic material in the grit and sand from septage. This will reduce the volume of grit and sand for final disposal. Eikum (1980) reports in Table 3.1 values for screening, grit and sand.

At Tønsberg Treatment Plant the quantity of screenings was measured after each truck load. The volume varied from 1.0 to 8.5 l/m^3 septage. These values agree quite well with that found at Brandbu Treatment Plant. In this case the volume of screening was 7.0 l/m^3 septage during one month period. At both of these treatment plants the mechanically cleaned bar screens had a clear space of 10 mm and a total width of 0.5 m.

At Enga Treatment Plant the volumes of screenings, grit and sand were measured during a three year period. This is shown in Figure 3.1.

As expected, the volume of material removed from the preliminary treatment units does increase with increasing volume of septage received. It does not, however, fluctuate as much as the volume of septage received since, when the

TABLE 3.1. SCREENINGS, GRIT AND SAND REMOVAL (Eikum, 1980)

Plant	Spacing screen mm	Screenings l/m^3 septage	Screenings, grit and sand l/m^3 septage	Comments
Tønsberg	10	1.0-8.5 1)	-	1) Based on measurement on each truck load.
Brandbu	10	7.0 2)	-	2) Average monthly value.
Enga 1977	10	-	27 3)	
" 1978	10	-	30 3)	3) Yearly average includes screenings.
" 1979	10	-	42 3)	

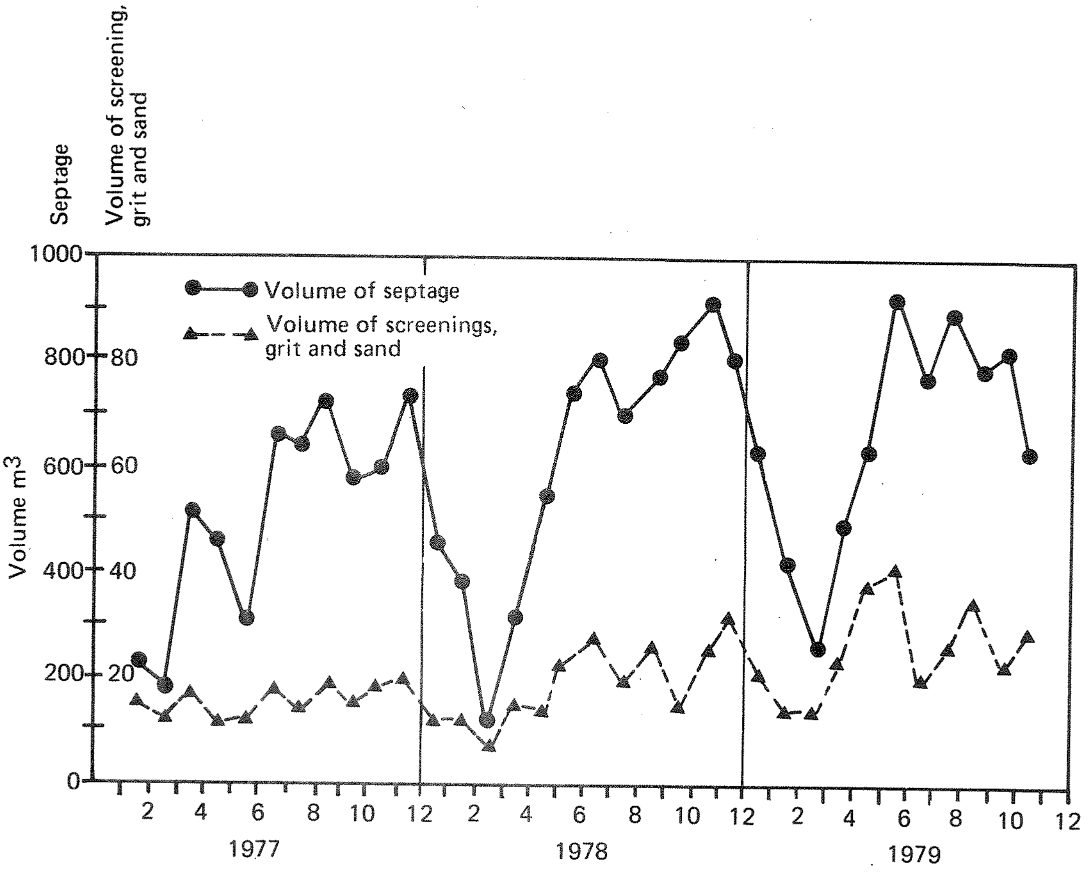

Figure 3.1. Volume of screenings, grit and sand at Enga Treatment Plant, Norway.

volume of septage to the plant is very high, the efficiency of the preliminary treatment units decreases. Thus the amount of screenings, grit and sand per m^3 of septage will decrease. The subject of preliminary treatment of septage will be covered in detail in Section 4.

ORGANIC AND INORGANIC MATERIAL IN SEPTAGE

In general there is great interest in the solids content of septage. The reason for this is that design of important unit processes like thickening, stabilization, dewatering and ultimate disposal are based on the weight of solids to be processed, as well as the total volume of septage. Wide variation of solids concentration data is found in the literature. This is attributed to the time interval between each cleaning of the tanks, size of the tanks, sampling of procedure, etc. It is difficult to pinpoint the effect of each of these factors since very little information is usually given regarding sampling procedure, tank sizes, etc. Work has been done to find the influence of solids retention time in the septic tank and its effect on the septage characteristics.

Resch (1979) reports on a study done by Kainz (1977) in Munich, Germany. Table 3.2 shows that an increase in solids retention time (time period between each cleaning operation) will cause an increase in the dry solids content of the septage. Also the BOD_5 and the COD of the filtrate will increase.

A similar investigation was done by Lohne (1980). He tried to correlate the solids content of the sludge pumped out of the tank as a function of the time period between each cleaning of the tank. Table 3.3 shows the result of his investigation.

The work done by Kainz (1977) and Lohne (1980) indicates that the solids retention time in the tank has an effect on both the solids content and the filtrate quality.

Løken (1973) investigated the characteristics of septic tank sludges in Norway. Figures 3.2, 3.3, 3.4, and 3.5 show the results where solids content is plotted versus cumulative percentage of observations. As indicated earlier, the variation in total solids content is great. Figure 3.2 shows that in 60 percent of the observations made (between 20 percent and 80 percent) the septage varies between 24,000 mg/l and 62,000 mg/l. The total volatile solids found (see Figure 3.3) do not vary to the same extent. This is due to the fact that when the extremely high values of total solids are found, this is largely caused by large amounts of sand and even stones in the septage.

Figures 3.6 and 3.7 show the volatile solids and volatile suspended solids as percent of total solids or total volatile solids respectively. The results agree well with those found by Kolega (1971) who determined the VSS as 82.5 percent of TSS.

Table 3.4 shows the characteristics of septage found in Germany, France, and Norway. The difference in solids content of the sludges in Germany and France compared to Norway is most probably due to the time interval between pumping. In Germany and France it is customary to empty the tanks more often than in Norway.

TABLE 3.2. SEPTAGE CHARACTERISTICS AS A FUNCTION OF CLEANING FREQUENCY (Kainz, 1977)

Parameter	Mean mg/l	Time interval between each cleaning <6 month mg/l	6-12 months mg/l	>12 months mg/l
TS	17 080	13 450	16 500	18 100
BOD_5 (Filtrate)	970	730	1 130	1 100
COD (Filtrate)	2 900	2 075	2 840	4 725
Org. acids	800	600	860	1 120
H_2S	45	22	48	130
No. of samples	86	40	31	15

TABLE 3.3. TOTAL SOLIDS AND VOLATILE SOLIDS IN SEPTAGE AS A FUNCTION OF CLEANING FREQUENCIES (Lohne, 1980)

Time between each cleaning years	Total solids (TS) % by weight	Total volatile solids % of TS	pH
0.3	5.9	92	5.3
2	4.5	69	6.3
4	3.5	58	6.6
4.5	6.3	78	6.0
6	10.1	77	5.2
9	9.7	53	6.9

It is pointed out by Aloisi de Larderel (1980) (personal communication) that the different parameters of septage will vary considerably between the different regions in France. It is mentioned that in the southwest of France the mean total suspended solids content of septage is as low as 3800 mg/l while in eastern France it varies between 11,000 and 67,000 mg/l. The corresponding value for northern France is 10,000 to 40,000 mg/l.

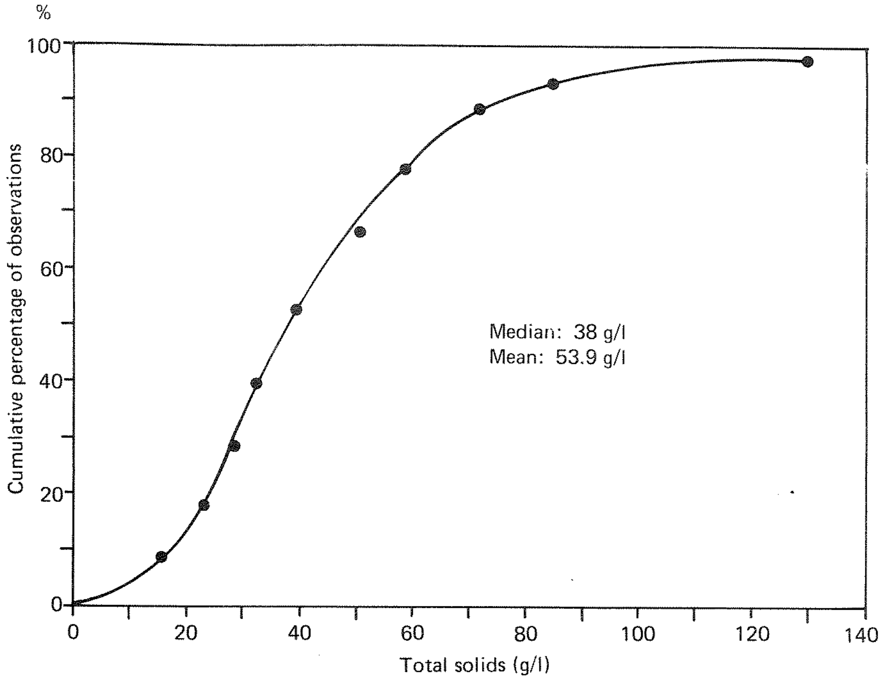

Figure 3.2. Total solids (S) in septage (Løken, 1973).

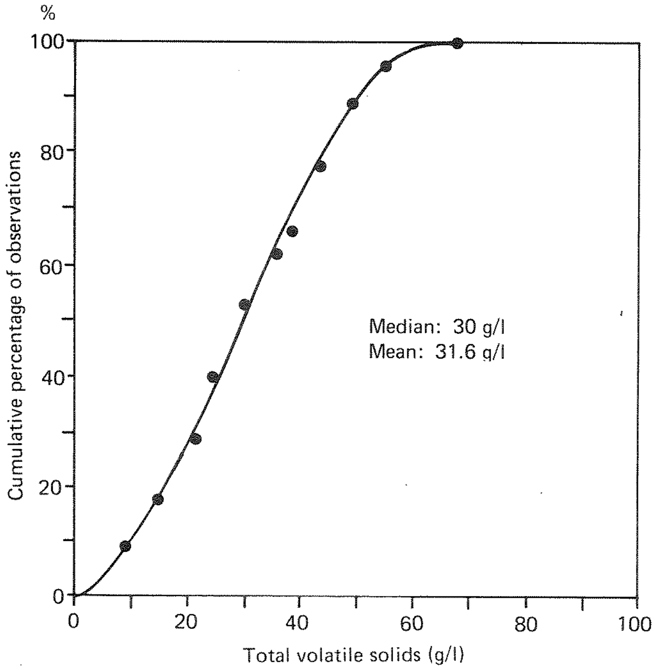

Figure 3.3 Total volatile solids (VS) in septage (Løken, 1973).

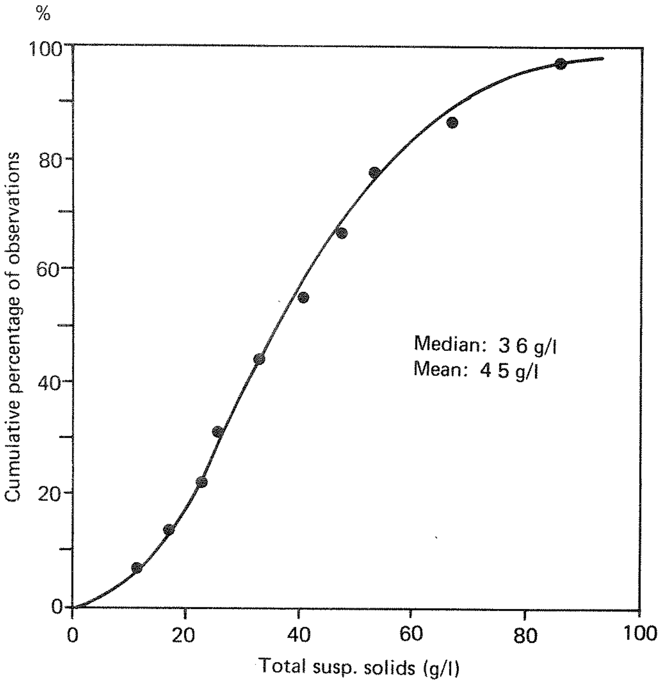

Figure 3.4. Total suspended solids (TSS) in septage (Løken, 1973).

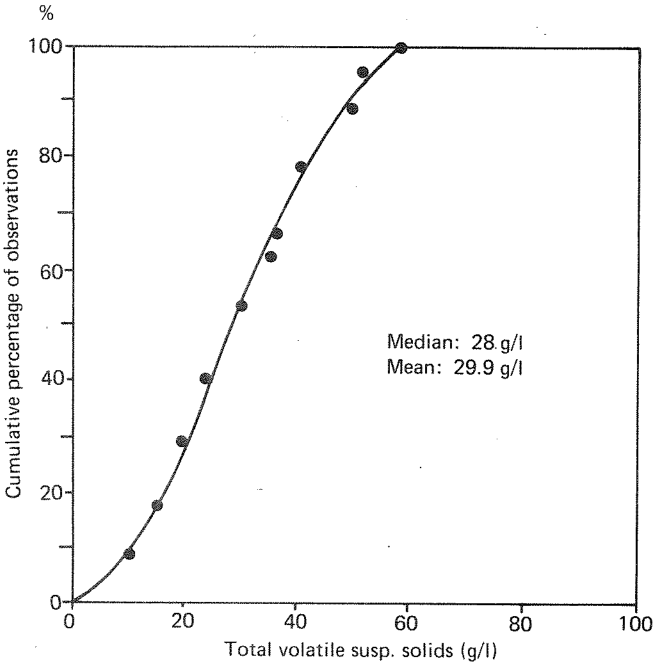

Figure 3.5. Total volatile suspended solids (VSS) in septage (Løken, 1973).

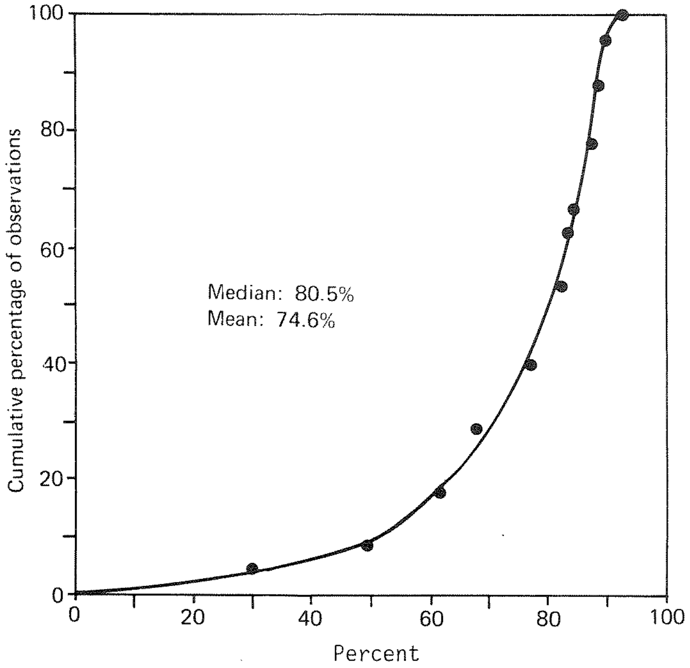

Figure 3.6. Volatile solids in percent of total solids in septage (Løken, 1973).

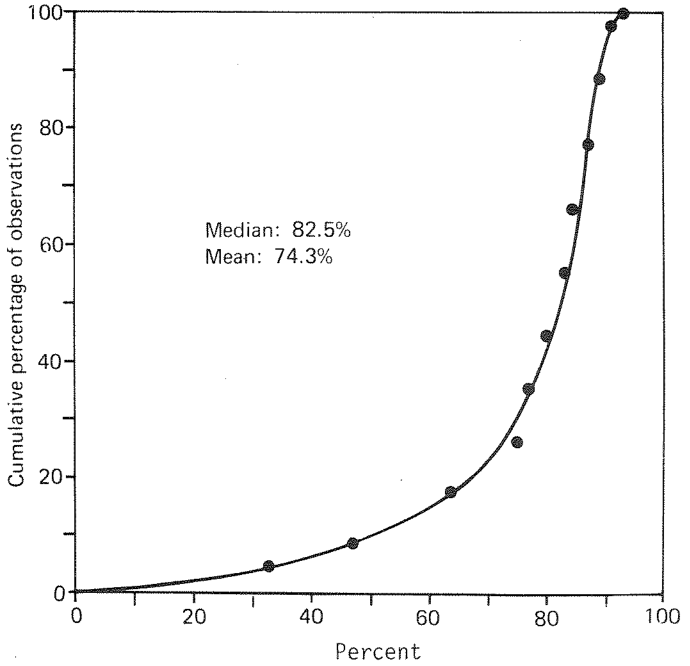

Figure 3.7. Volatile suspended solids in percent of total suspended solids in septage (Løken, 1973).

TABLE 3.4 CHARACTERISTICS OF SEPTAGE IN SOME EUROPEAN COUNTRIES

Parameter	Germany			France		Norway			
	ATV (1973)	Resch (1979)		Aloisi de Larderel (1980)		Løken (1973)		Eikum (1976)	
mg/l		Mean	Range	Mean	Range	Mean	Range	Mean	Range
TS	15 000	14 000	200-75 000	-	-	53 900	6050-123 860	-	-
VS	10 000	10 100	160-50 000	-	-	31 600	4360- 67 570	-	-
TSS	-	-	-	-	5000-10 000	45 000	4650- 70 920	45 370	6510- 68 130
VSS	-	-	-	-	4000- 8 000	29 900	4180- 49 060	33 830	5570- 52 370
BOD_5 septage	10 000	4 700	700-25 000	-	3000-10 000	10 330 2)	2725- 23 780 2)	-	-
BOD_5 filtrate	-	1 140	100- 4 300	-	-	744 2)	103- 4 192	-	-
COD septage	16 000 1)	15 300	1300-65 000	20 000	2000-50 000	42 550	8460- 82 400	64 530	1630-114 870
COD filtrate	-	3 100	400-28 000	-	-	1 698	363- 6 890	3 870	280- 5 280
Total-N	2 300	535	150- 1 400	-	-	793	297- 1 561	1 080	126- 2 570
NH_4-N	1 600	280	100- 550	-	1000- 2 000	113	70- 235	157	35- 287
Total-P	-	150	25- 400	-	-	171	36- 636	138	20- 330
H_2S	-	45	2- 250	-	-	-	-	-	-
pH	-	7.0	5.5-9.0	8.2	7 - 9	6.55	5.2-7.8	6.3	5.5-7.8

1) $KMnO_4$ value. 2) Measured as BOD_7.

BIOCHEMICAL - AND CHEMICAL OXYGEN DEMAND OF SEPTAGE

Untreated septage contains a large fraction of biodegradable organic material. Considering the origin of this sludge, this is to be expected. Table 3.4 shows typical values for both BOD_5 (or BOD_7) and COD variations in different European countries. Again, wide variations in values were experienced. This is natural since the volatile solids content also varies. Løken (1973) looked at the correlation between COD, BOD, and content of volatile solids in septage. The result of COD vs. VSS is shown in Figure 3.8. He found the correlation between BOD_7, COD, and VSS given in Table 3.5.

TABLE 3.5. CORRELATION BETWEEN BOD_7, COD, AND VSS IN SEPTAGE (Løken, 1973)

Parameter	No. of samples	Coeff. of correction	Equation
BOD_7 as a f.of VSS*)	40	0.72	$BOD_7 = 0.27 \text{ VSS} + 2130$
COD " " " " VSS	43	0.80	$COD = 1.14 \text{ VSS} + 8590$
BOD_7 " " " " COD septage	40	0.68	$BOD_7 = 0.18 \text{ COD} + 2520$
BOD_7 " " " " COD liquor	38	0.80	$\log BOD_7 = 1.23 \log COD - 1.24$

*) as a f.of = as a function of --

Resch (1979) found the BOD_5 in septage to vary between 700 and 25,000 mg/l with a mean value of 4700 mg/l. The mean value of BOD_7 found by Løken (1973) is more than twice (see Table 3.4 and Figure 3.9) the value reported by Resch. This is as expected since the VSS content found by Løken is substantially higher. It must be taken into account that BOD_7 is approximately 1.20 times BOD_5.

Baumgart (1981) estimated the specific BOD_5 and COD values for septage. Based on a 0.95 m^3 septage per person per year, he found 4.5 kg BOD_5/p.yr. in the septage sludge and 1.1 kg BOD_5/p.yr. in the septage liquor. The corresponding COD values were 14.5 kg COD/p.yr. and 2.9 kg COD/p.yr. In his work Baumgart reports BOD_5 and COD values in septage from different treatment facilities in Germany. These are given in Table 3.6.

In a study in England on treatment of cesspool waste the BOD_5 was found to be 2270 mg/l with a corresponding TSS value of 3972 mg/l. The values are based on manual weekday samples once every week from October 1971 to February 1972. (Dept of the Environment, 1975.)

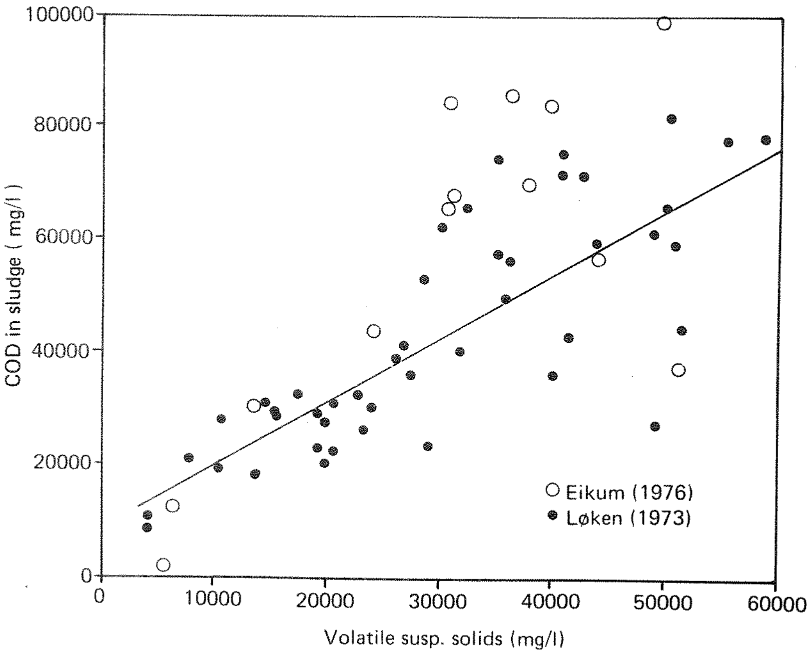

Figure 3.8 COD versus VSS in septage.

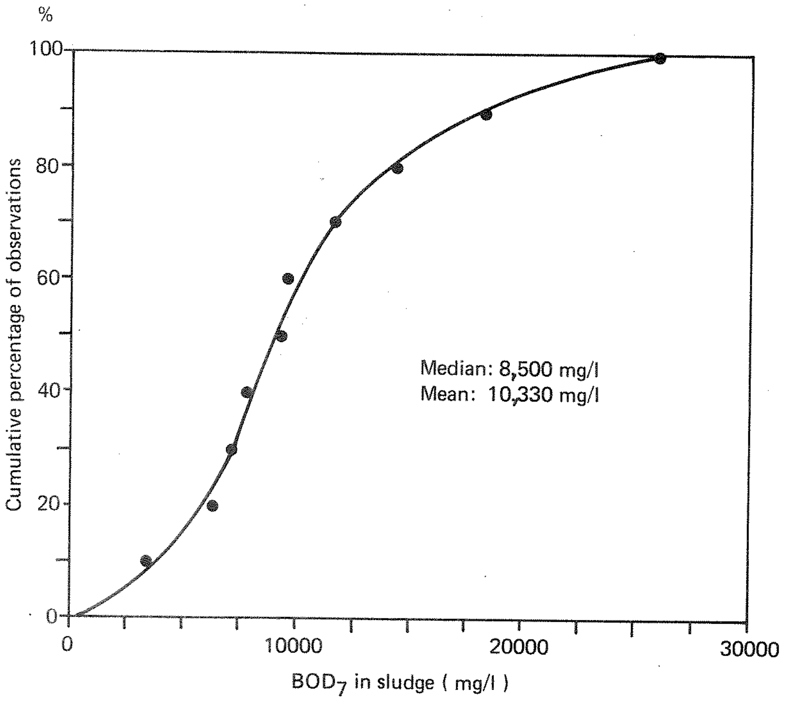

Figure 3.9 BOD_7 in septage (Løken, 1973.

TABLE 3.6. BOD_5 AND COD VALUES OF SEPTAGE IN GERMANY (Baumgart, 1981)

Municipality/treatment plant	BOD_5 mg/l	COD mg/l	Reference
Hessische Landesanstalt für Umwelt	3000	-	Hessische Landesanstalt (1976)
Abwasserverband München-Ost	4750	-	Baumgart (1981)
Hamburger Klärwerk Stellinger Moor	4500	-	Kleffner (1972)
Ruhrverband Essen	9500 (2200-22900)	-	Ruhrverband Essen (1967)
Tiefbauamt Augsburg	1500-2300	4600-10500	Baumgart (1981)
Hamburger Klärwerk Bergedorf	-	4500-7700	Baumgart (1981)

NITROGEN AND PHOSPHORUS IN SEPTAGE

With the growing interest in nutrient removal from wastewater the nitrogen and phosphorus in the septage is of concern. Information on nutrient content in septage liquor is given in Section 6.

Løken (1973) found the mean phosphorus and nitrogen content of septage to be 171 mg P/l and 793 mg N/l, respectively. These data are shown in Figures 3.10 and 3.11. Based on the content of dry solids, we find 3.80 g P/kg TSS and 17.6 g N/kg TSS.

Resch (1979) reported P and N (total) content of septage to be 150 and 535 g/l, respectively. This will be 10.7 g P/kg VS and 38.2 g N/kg VS. These values are higher than those given by Løken. A possible explanation was thought to be that the shorter time period between pumping in Germany will result in less biological activity in the septic tank and thus less nutrients, especially nitrogen in the sludge liquor. Since Resch reports 280 mg NH_4-N/l in the sludge liquor while Løken found 113 mg NH_4-N/l, this is evidently not true.

HEAVY METALS IN SEPTAGE

The final disposal alternatives available for any type of sludge will depend on the quality of the sludge to be disposed of. The content of heavy metals in septage is of concern in this respect.

Considering the origin of septage, high concentrations of heavy metals are not expected.

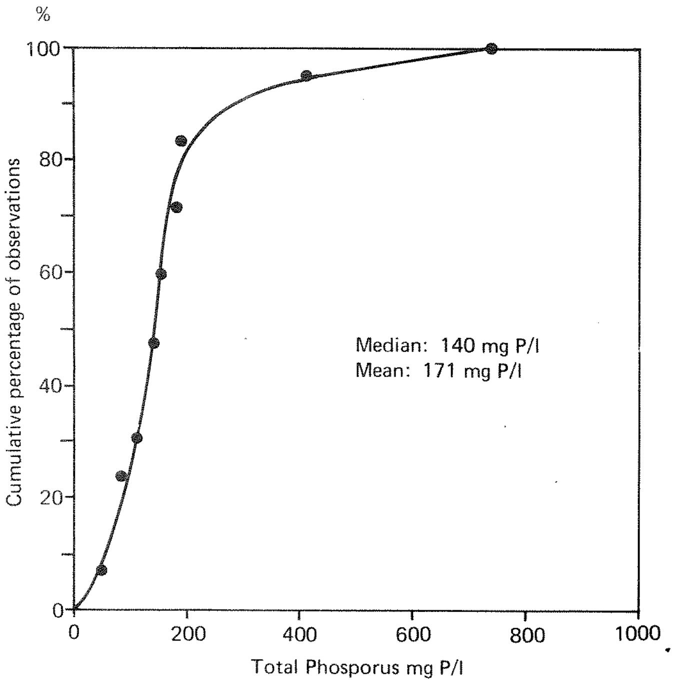

Figure 3.10. Total phosphorus in septage (Løken, 1973).

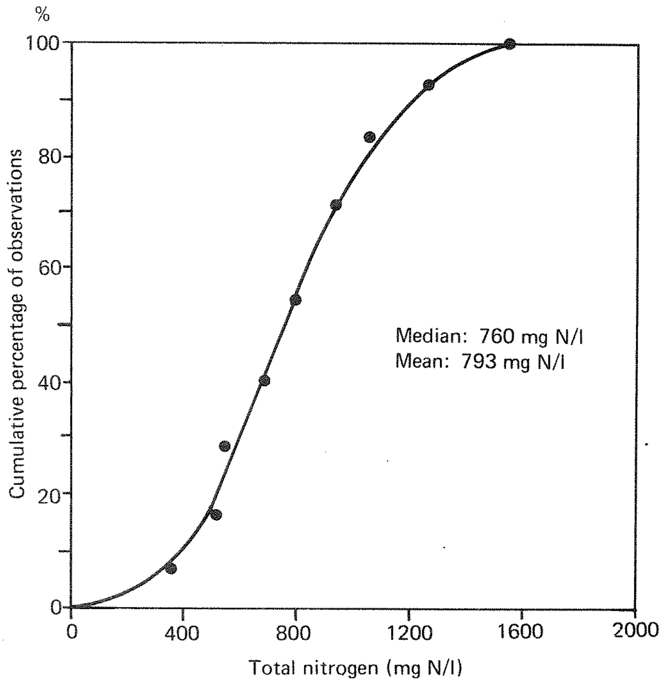

Figure 3.11. Total nitrogen in septage (Løken, 1973).

Martinsen (1973) compared the content of heavy metals in septage with municipal sludges from two municipal wastewater treatment plants. This is shown in Table 3.7. The content of metals in septage was generally lower than that found in the sludges from the two municipal plants. Both municipal plants had phosphorus removal. The reason for the higher metal concentrations in the municipal sludges is the industrial waste contribution.

TABLE 3.7. METALS IN SLUDGES (Martinsen, 1973)

Metals		Septage mg/kg TS	Løxa Treatment Plant mg/kg TS	Oslo Treatment Plant mg/kg TS
Lead	(Pb)	59 - 121	400	370
Mercury	(Hg)	6 - 8	10	10
Zink	(Zn)	530 - 721	770	1650
Copper	(Cu)	340 - 466	1280	1500
Cromium	(Cr)	30 - 64	52	1250
Cadmium	(Cd)	4 - 6	< 5	18
Nickel	(Ni)	23 - 30	19	70

Baumgart (1981) investigated the heavy metal content of septage in Munich, Germany. Samples were taken from 40 trucks hauling septage. The results are shown in Table 3.8. The values agree well with those found by Martinsen (1973). Only the content of copper was higher in septage in Norway. This is probably due to more corrosive drinking water in Norway than in central Europe.

TABLE 3.8. AVERAGE CONTENT OF METALS IN SEPTAGE (Baumgart, 1981)

mg/kg TS	Cd	Cr	Cu	Ni	Pb	Zn
Septage in Munich	2.1	25	186	23	155	1 544
Range	0-14	0-200	50-600	0-100	0-850	300-3 600
State Limits-BMI primary sludge	30	1 200	1 200	200	1 200	3 000
State Limits-BMI soil	3	100	100	50	100	300

Substantial research has been carried out in US on heavy metals in septage (Kreissl, 1976; Cooper et al., 1976; EPA, 1977). These studies also showed the heavy metal content in septage to be much lower than that found in municipal sludges.

PATHOGENS IN UNTREATED SEPTAGE

Most countries have restrictions regarding the hygienic quality of sludges to be disposed of in agriculture. It is therefore important to know the hygienic quality of septage and what effect different treatment processes will have on it. The latter topic will be covered in Section 4. Only the quality of untreated septage will be discussed in this section.

Table 3.9 summarizes some of the investigations carried out at NIVA.

The concentrations of pathogenic organisms in septage are in the same range as found in sludges from municipal treatment plants. Table 3.9 also indicates that although variations will be found regarding concentrations of pathogens in septage, the concentrations are high for all the indicator organisms used. This is also true for contents of a holding tank (Paulsrud, 1980).

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TABLE 3.9. PATHOGEN CONCENTRATIONS IN DOMESTIC SLUDGES

Type of sludge	Organisms/100 ml sludge				Reference
	Total coliforms 37 ^{o}C	Fecal coliforms 44 ^{o}C	Fecal streptococcus	Anaerobic sporeformers, *Clostridium perfringens*	
Septage	$3.5 \cdot 10^{7}$	$3.9 \cdot 10^{6}$	$4.7 \cdot 10^{3}$	$3.3 \cdot 10^{5}$	Paulsrud, 1975
Septage	$3.4 \cdot 10^{5}$	$3.0 \cdot 10^{4}$	$4.8 \cdot 10^{3}$	$3.0 \cdot 10^{4}$	Eikum, 1981
Primary	$5.6 \cdot 10^{7}$	$2.0 \cdot 10^{7}$	$1.1 \cdot 10^{6}$	$3.4 \cdot 10^{5}$	Paulsrud, 1975
Primary-chem. (Al)	$4.6 \cdot 10^{7}$	$2.8 \cdot 10^{7}$	$2.7 \cdot 10^{6}$	$> 1.0 \cdot 10^{4}$	Paulsrud, 1975
Holding tank	$2.0 \cdot 10^{6}$	$3.4 \cdot 10^{5}$	$1.8 \cdot 10^{6}$	-	Paulsrud, 1980

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SECTION 4

PRETREATMENT OF SEPTAGE

Septage contains rags, grit, sand, plastic, and other inert material that have to be removed in order to protect unit processes downstream from the screen and grit chamber at the receiving treatment facility. Field investigations have shown that the pretreatment step is the major source of operational problems at plants receiving septage. On the other hand, interviews with wastewater treatment plant operators often show that unacceptable performance of pretreatment units at one plant causes no or only minor problems at another plant.

In the following section, discussion will focus on pretreatment units used in Scandinavia and elsewhere and the advantages and disadvantages that have been experienced. For screening, grit, and sand quantities, see Section 3.

PRETREATMENT UNITS - FLOW SCHEME

There are many ways to design the pretreatment facilities at plants receiving septage. Until recently, no guidelines existed in Scandinavia, and the matter was left to the individual plant designer. Many mistakes have been made. However, during the last four years the methods and practice have improved regarding pretreatment and handling of septage.

The most significant fact that experience has revealed, is that septage handling cannot be fully automated. Manual labor is necessary to obtain reliable treatment. Figure 4.1 shows examples of the most common pretreatment systems in Scandinavia. A pretreatment system usually consists of a receiving facility, one or two screens, an aerated grit chamber, and a septage storage tank. At some plants a pumping step is placed between the screen and the grit chamber. In some cases the grit chamber is omitted where subsequent processing is unaffected by the presence of grit.

In this section the design and performance of the receiving facility, the screen, and the grit chamber are discussed. These three units are the most important ones in the pretreatment process for septage.

Regarding the design flow for the pretreatment units, it must be able to handle the maximum truck load received at the plant. In Scandinavia this varies between 3 m^3 and 15 m^3. The most common tank size used is 6-8 m^3.

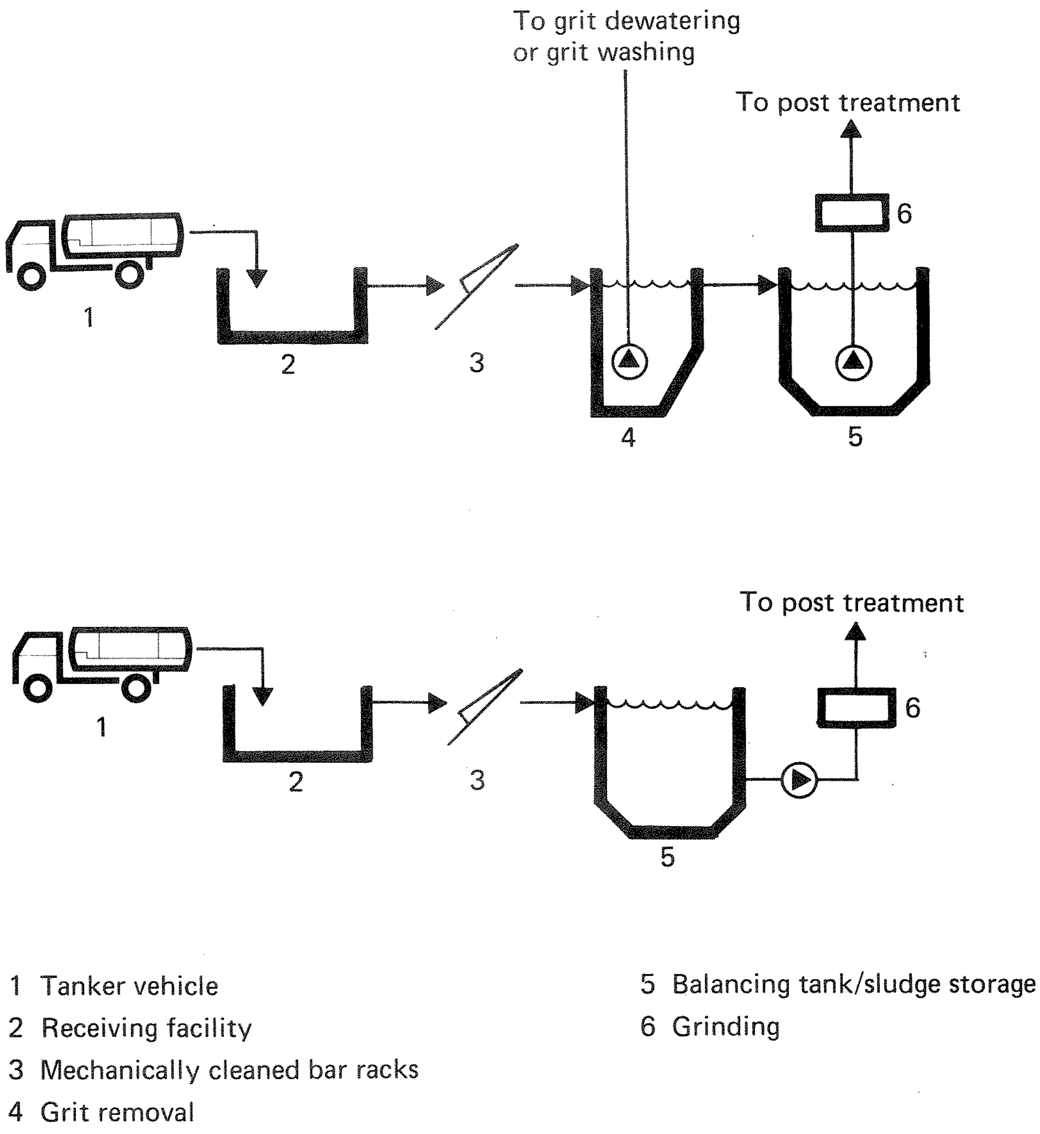


Figure 4.1. Common pretreatment units for handling septage.

RECEIVING FACILITY

Several design considerations must be made when septage is to be received at a sewage treatment plant.

- The area in front of the discharge point must be large enough to enable the tank trucks to maneuver into a position for unloading.
- The traffic area must have asphalt or concrete pavement and be easy to clean. It should slope to a central drain.
- A water hose with sufficient capacity and length for thorough cleaning must be present. In areas with cold climates hot steam equipment should be available for loosening frozen valves, etc. on the tank trucks.

The receiving tank where the septage is discharged, has been designed in many different ways. Figures 4.2, 4.3, 4.4, 4.5, and 4.6 show typical designs. Quite often the inlet has a physical shape so that the tank truck can back up to the discharge point without any hose connection. (See Figures 4.2 and 4.3.) This type of solution can easily result in spillage around the inlet point. The odor problem will also be substantial when using this method since odorous gases are stripped from the septage by the violent turbulence of the unloading procedure resulting in the release of odorous gases outside the building.

Typical designs for hose connection are shown in Figures 4.4 and 4.5. It is difficult to prevent spillage with these alternatives when the hose is disconnected. Figure 4.6 shows a combined solution where the truck can either discharge the sludge directly or use the hose connection. This solution is recommended for areas where different types of vehicles are used for sludge hauling.

Based on the experience with several different types of septage discharge units in Norway, the recommended design is shown in Figure 4.7. The hose connection is made inside a box with a cover. This will prevent spillage outside the treatment plant since it will drain into the receiving channel. The bottom in the concrete structure has heating cables to prevent freezing problems during the winter.

Discharge of septage into a sewer will require a similar type of receiving facility as those discussed above. In many countries the manholes serve as receiving facilities for septage, more or less without control.

In Germany a receiving facility for septage at treatment plants is designed differently than what is common in Scandinavia. In the southern part of Germany a receiving facility for septage is designed as shown in Figures 4.8 and 4.9. If the septage is fed into the treatment plant inlet, the design in Figure 4.8 is used. The truck connects to a hose connection and pumps the septage into the bottom of the cone shaped basin. The septage is then fed into the treatment plant before the screen. The detention time in the septage basin is in the range of 10-15 days, based on the average sludge quantity received. In periods with intensive sludge hauling, the detention time may be reduced to 1-3 days.

When the septage is fed into the sludge treatment stream of a wastewater treatment plant, the receiving facility is designed as shown in Figure 4.9. The septage enters a channel in front of a mechanically cleaned bar screen.

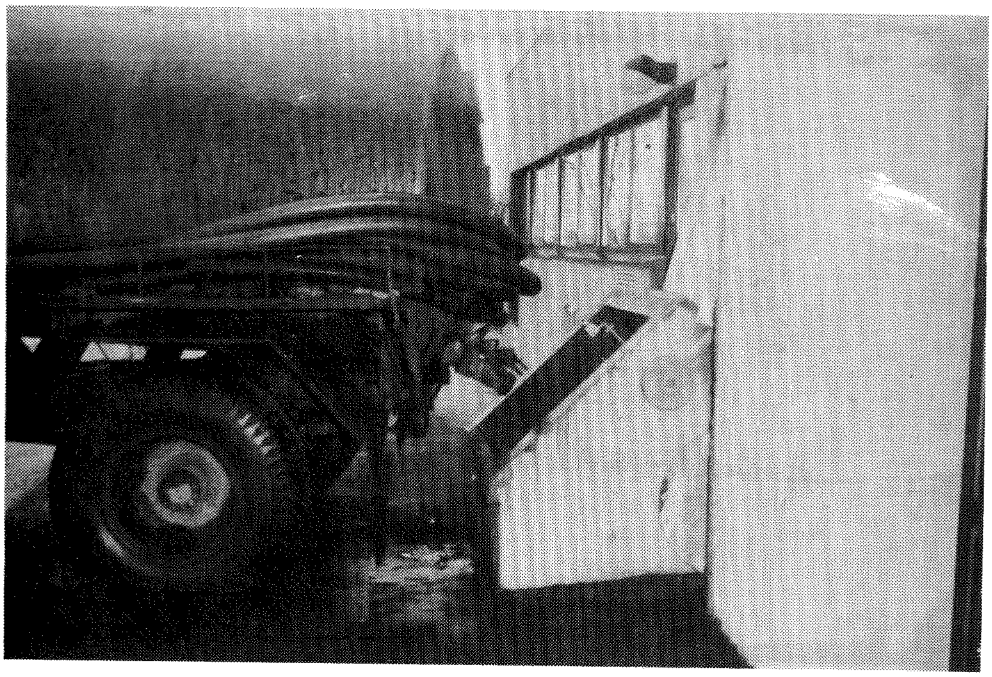


Figure 4.2 Sludge discharge without hose connection.

Figure 4.3 Receiving box with aluminum cover.

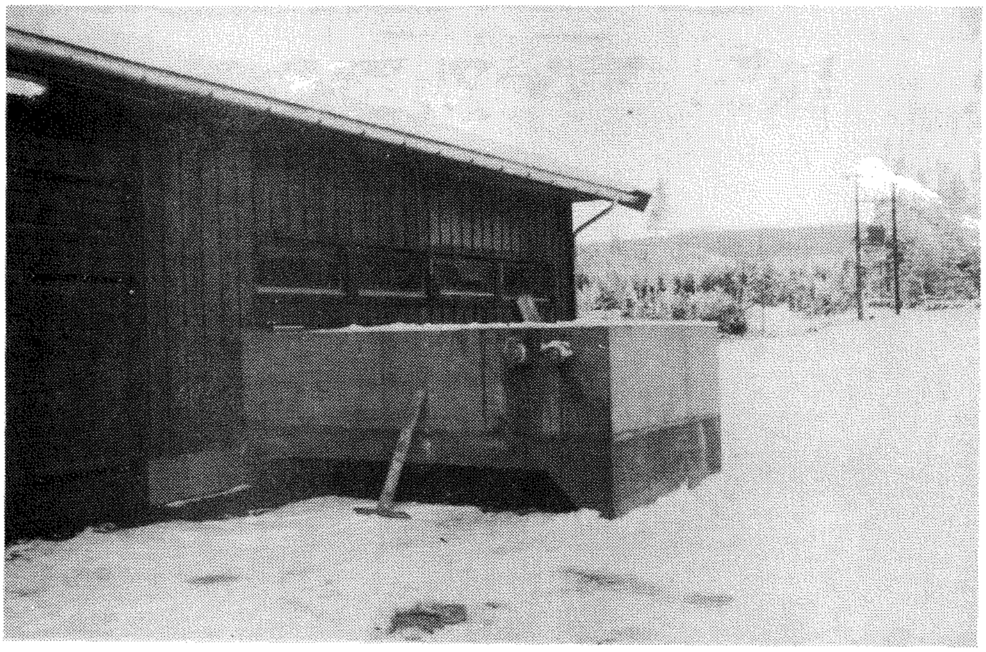


Figure 4.4. Hose connection for septage.

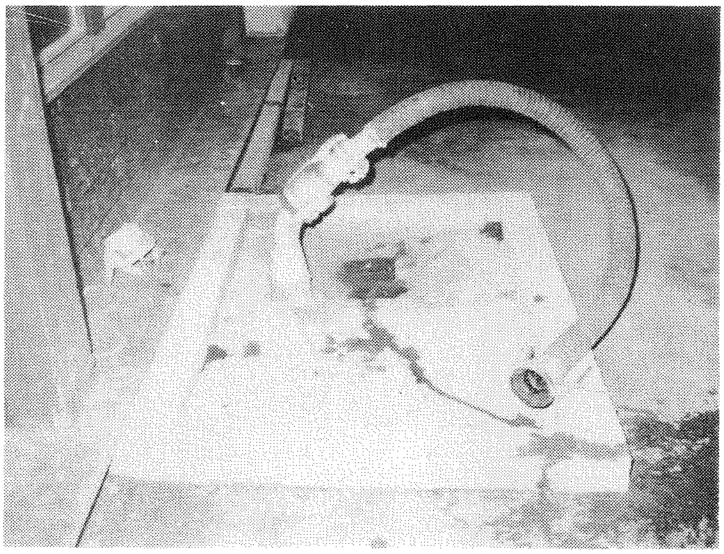


Figure 4.5. Hose connection for septage with small surrounding concrete apron to make cleaning operation easier.

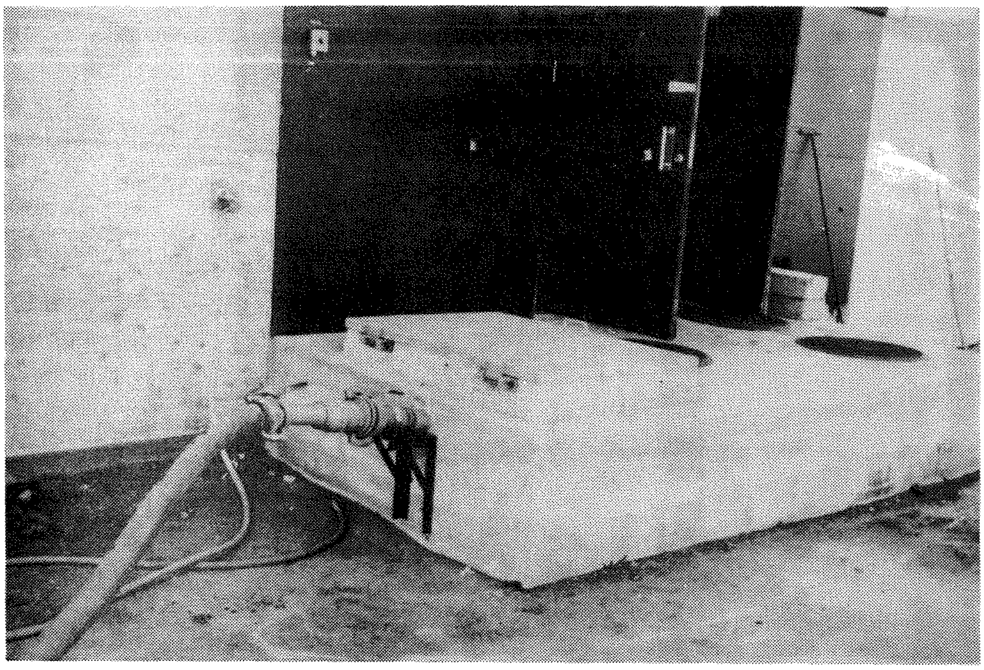


Figure 4.6 Combined hose connection and open discharge for septage.

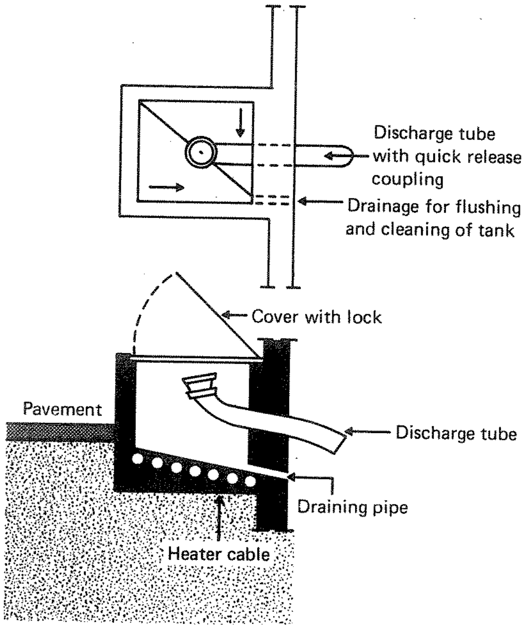


Figure 4.7 Recommended inlet arrangement when receiving septage.

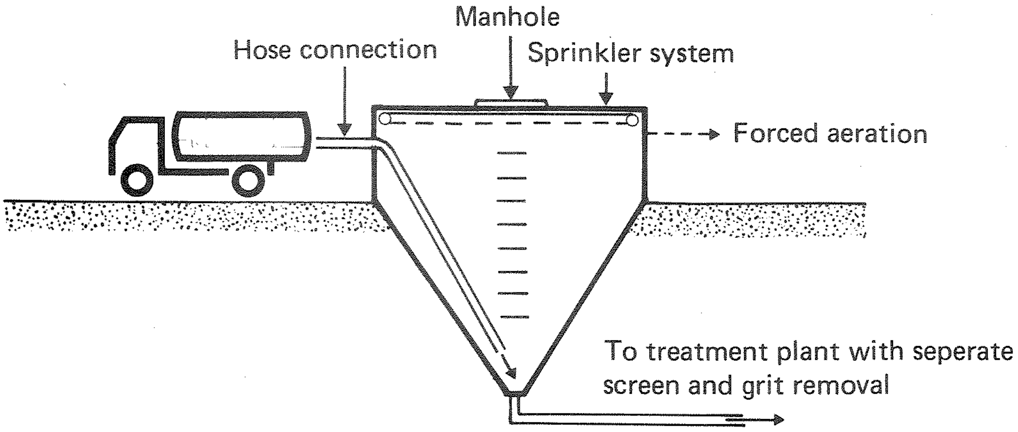


Figure 4.8a Receiving facility where the septage is fed into the treatment plant inlet (Baumgart, 1981).

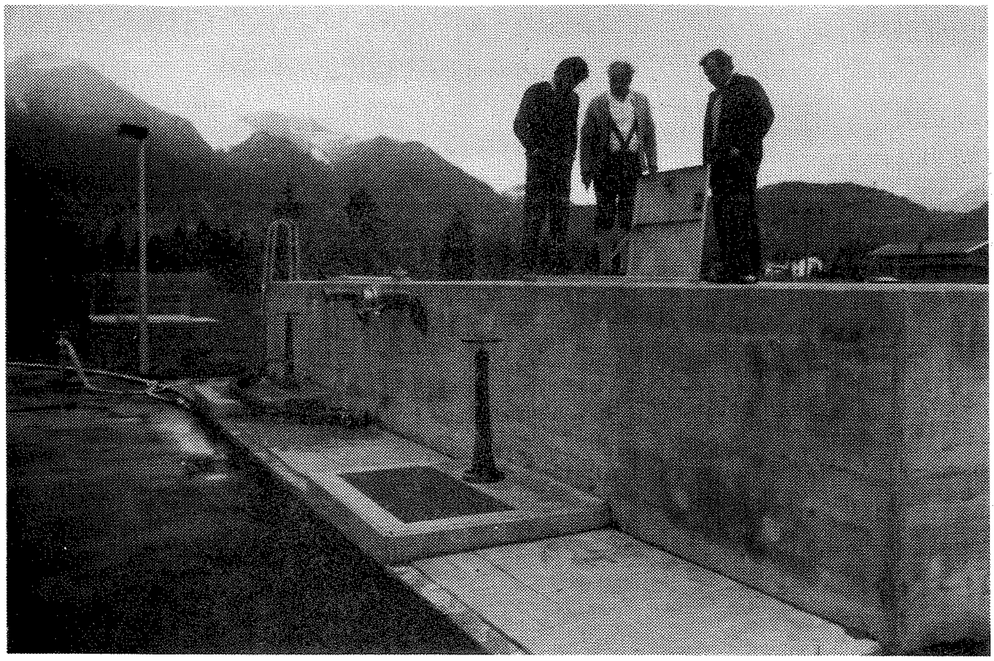


Figure 4.8b Outside view of the above receiving facility.

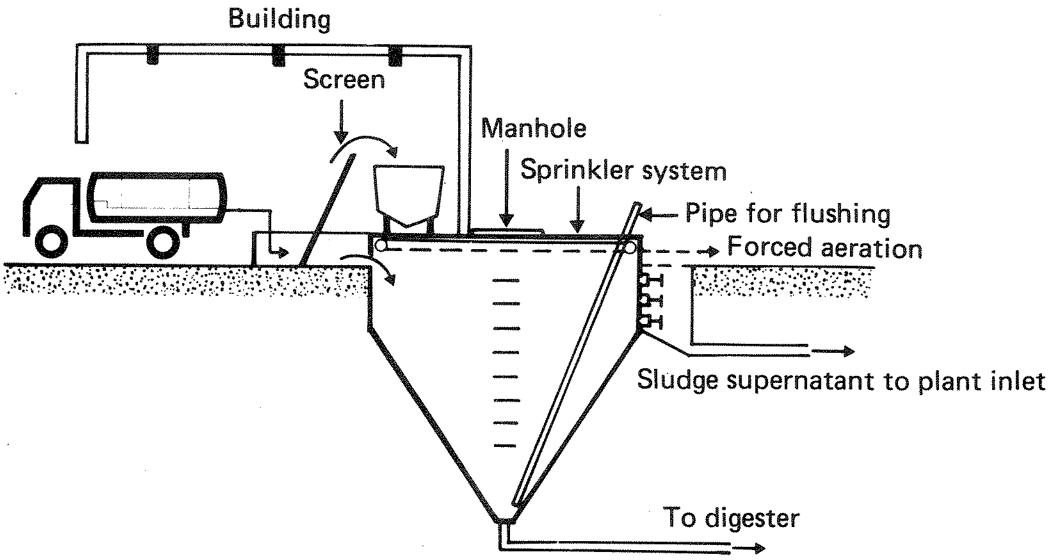


Figure 4.9a Receiving facility where the septage is fed to an anaerobic digester (Baumgart, 1981).

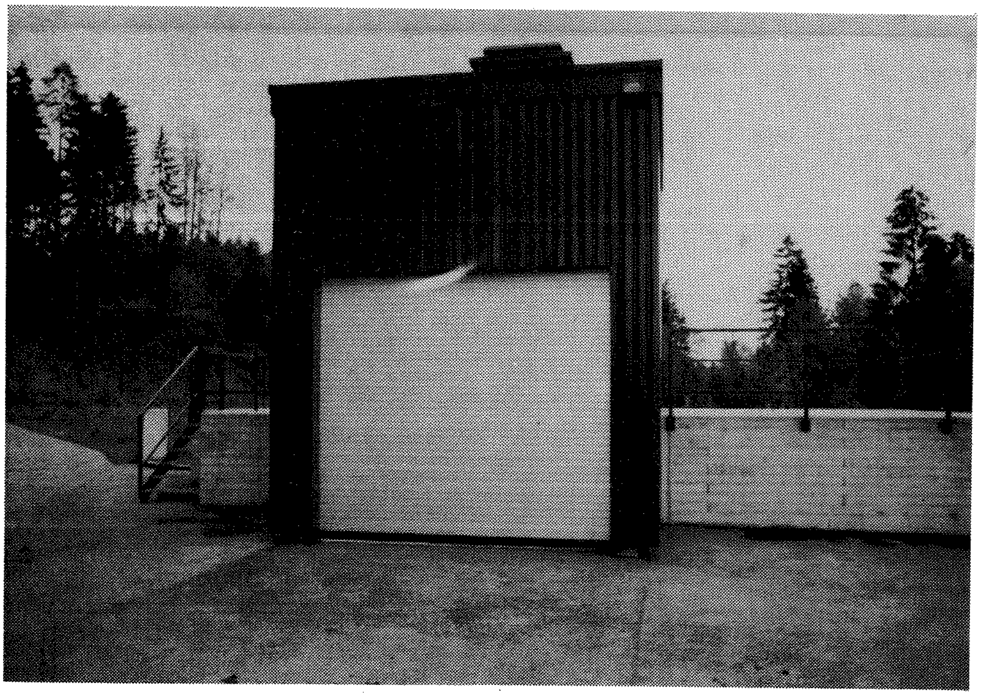


Figure 4.9b Outside view of the above receiving facility.

The septage then enters the sludge basin which is operated as a thickener. Sludge liquor is drawn off at the top and pumped to the treatment inlet. The thickened septage is pumped from the bottom of the tank and directly to the anaerobic digester. According to the operators at plants with facilities as shown in Figures 4.8 and 4.9, the operational problems with these facilities are minimal. The septage basin, however, must be equipped with a sprinkler system to ensure effective cleaning of the tank.

At Ekebyhov Treatment plant in Sweden, a similar design as the one discussed above, is in use. The conventional activated sludge plant serves a population of 8 000 persons, but has a design capacity of 20 000 persons. The plant also has a tertiary step removing phosphorus. The plant receives from 10 to 50 m^3 septage per day, but has a capacity to treat 50 m^3 per day. The design of the receiving facility is shown in Figure 4.10. The tank truck connects to a hose connection and pumps the septage directly into a sludge basin with a sloped bottom. The septage runs by gravity to the treatment plant inlet through a Ø 200 mm pipe with a valve at the end. The valve is used to control the flow of septage to the treatment plant inlet.

A submersible pump is used to recycle the septage in the holding tank. It is also possible to pump the septage from the tank to the plant inlet. According to the plant operators, very little maintenance is required with the receiving facility at Ekebyhov Treatment Plant.

In Germany it is quite common to discharge the septage into the sewer system. This is done under quite strict regulations regarding quantity of septage in relation to the wastewater flow, the type of treatment plant downstream, etc.

Figure 4.11 shows a system which is in use in several German cities. The system consists of one inlet box and two manholes. The first manhole contains a flow meter for measuring the volume of septage discharged to the sewer. In addition, a test pipe for taking samples is connected to the discharge pipe. The second manhole serves as a rough grit chamber where stones, etc. will be collected. This material is removed manually as often as found necessary. The discharge system for septage is connected to a liquid waste control computer developed by Reinhart Meyer Engineering in Germany (1981). The computer system is used for checking and recording information on the septage entering the sewer system. Each user of the system is issued with a coded card which may be used to activate the equipment, allowing a valve to be opened to enable waste to be deposited into the sewer. The equipment, with printer, emergency power supply, display, keyboard, isolated signal inputs and outputs, and a cardreader, is capable of determining "who" may deposit "how much" of "what" into the sewer system. In addition, it is possible to record the volume of waste deposited per user over a period of time and then, at the end of the month for example, to print out a list of all users and the quantities of waste deposited by each of them.

When setting up the user data records, it is possible to specify "checkmarks". This enables extra recording equipment (e.g. sample-takers or pen-recorders) to be switched on when these particular users access the system.

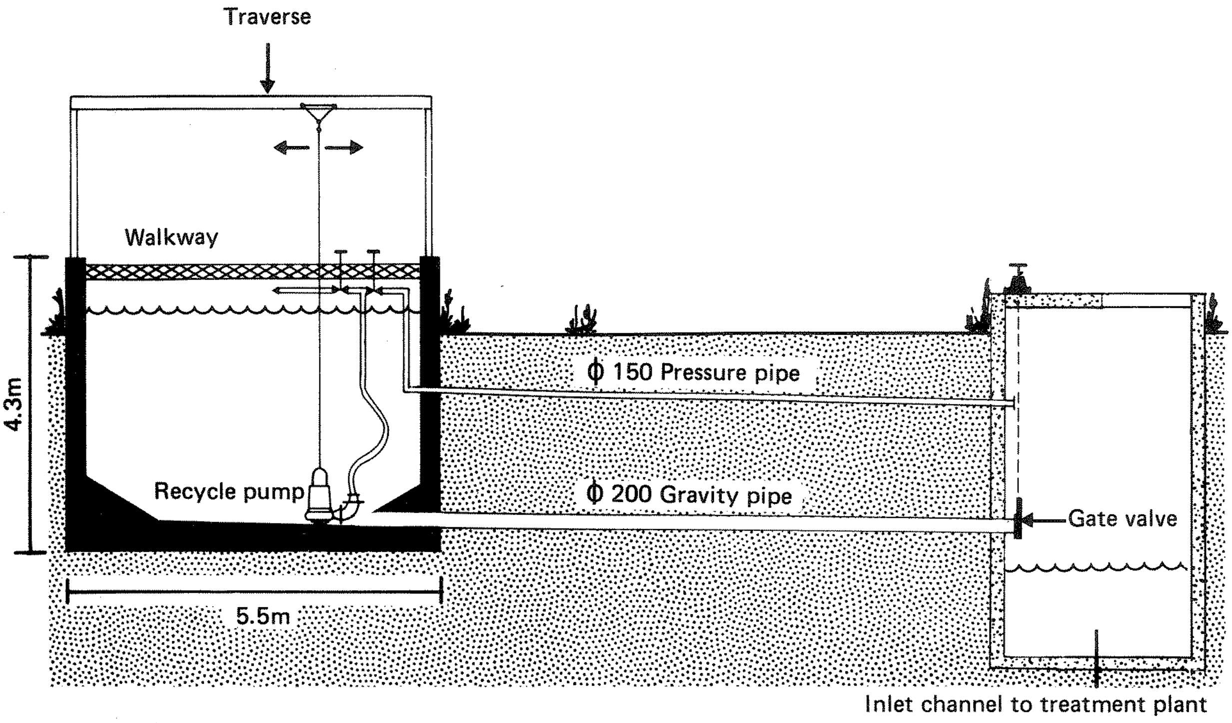


Figure 4.10a Receiving facility for septage at Ekebyhov Treatment Plant, Sweden.

Figure 4.10b Outside view of the receiving facility at Ekebyhov, Sweden.

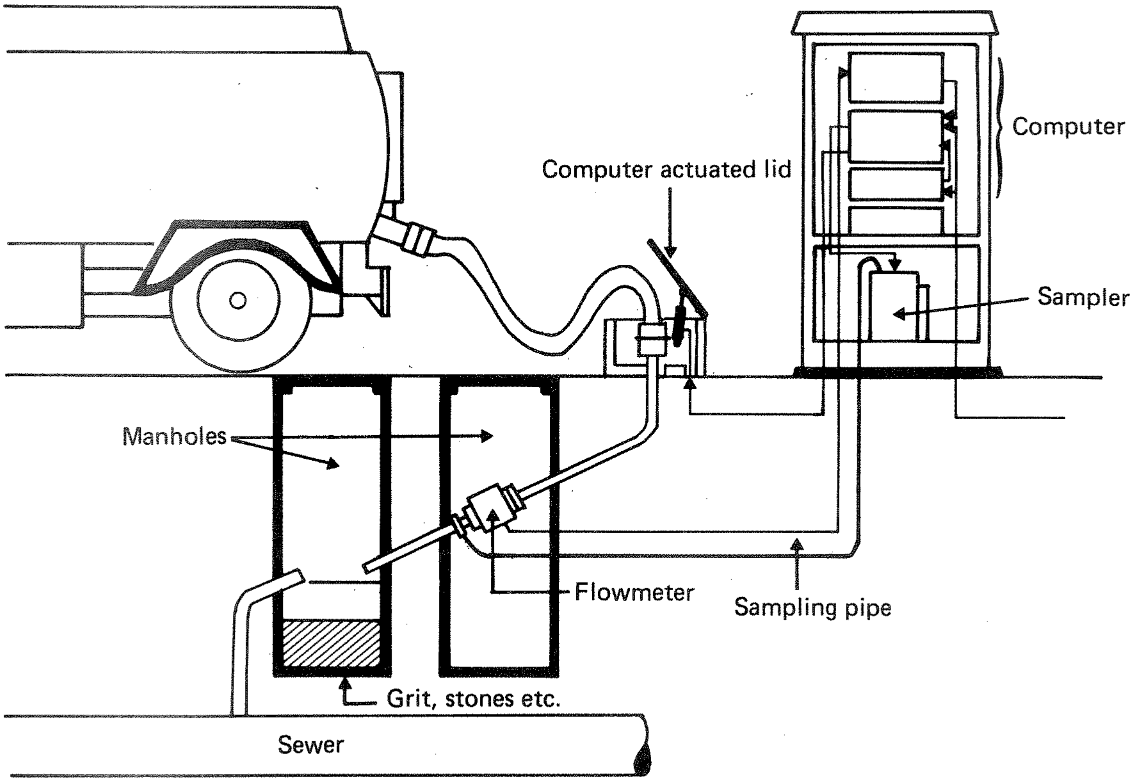


Figure 4.11. Septage discharge system in Munich, Germany. (Reinhart Meyer, Ingenieurbüro, 1981, personal communication.)

The ability to define the times of the day or week when deposits by particular users are allowed, makes this equipment suitable for a wide range of waste management applications.

Upper and lower limits for each data input may be set in via a keyboard. If the data value goes outside these limits, a message will be printed and a relay is operated to enable external action to be taken (e.g. sample-taker switched in). If the minimum or maximum value of a particular data range is observed, this is also recorded on the printer in case it implies a defective transducer.

The unit has an internal clock and calendar and headlines all printed messages with the date and time. The normal printout shows the values of up to the maximum of eight possible data-inputs. The period between these printouts may be adjusted via the keyboard, as can the characteristics of the transducer on this channel and the upper and lower data limits. It is therefore possible for eight freely selectable input channels to be logged and checked against limits.

Each individual channel may be checked at any time via a simple keyboard command, thus facilitating the checking and installation of transducers.

The system used in Germany enables the municipality to control the septage quantity and quality that enters either the sewer system or the wastewater treatment plant. To the authors' knowledge the system is not in use in countries besides Germany.

SCREENING

Mechanically cleaned bar screens are the type of screens that is most practical for the screening of septage. Manually cleaned bar screens and baskets (see Figures 4.12 and 4.13) have been used, but are not recommended since the handling of screenings is an unpleasant job and should be avoided.

Different types of mechanically cleaned screens are in use at plants receiving septage (see Figure 4.14). It is important that the bar screen is designed to handle more and heavier material than an ordinary screen designed for sewage. The mechanically cleaned bar screen should have no moving parts, such as chains and wheels installed under water level. Experience in Norway shows that such devices always cause operational problems. The material standard for parts in contact with the septage should be stainless steel; this is true for both the bars and the fork.

The space between the bars is an important design parameter. Too narrow spacing causes clogging and increased organic matter in the screenings. Too wide space between the bars causes rags etc. to pass, resulting in clogging problems downstream. The recommended space between the bars is 10 mm.

Mechanically cleaned bar screens can be either front-cleaned or back-cleaned. Also models with fully rotating forks are manufactured. The most common type is the front-cleaned model with an up- and down-moving fork.

Depending on the yearly amount of septage to be treated, one must consider the use of two or more bar screens operating in parallel. A bypass channel with a manually cleaned bar screen is recommended.

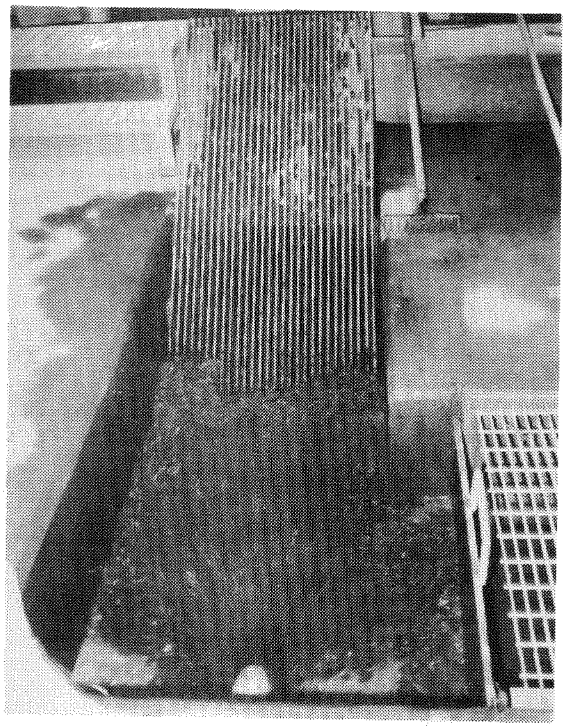


Figure 4.12 Manually cleaned bar screen, previously used at Brumunddal Treatment Plant, Norway, The discharge pipe is placed too close to the screen.

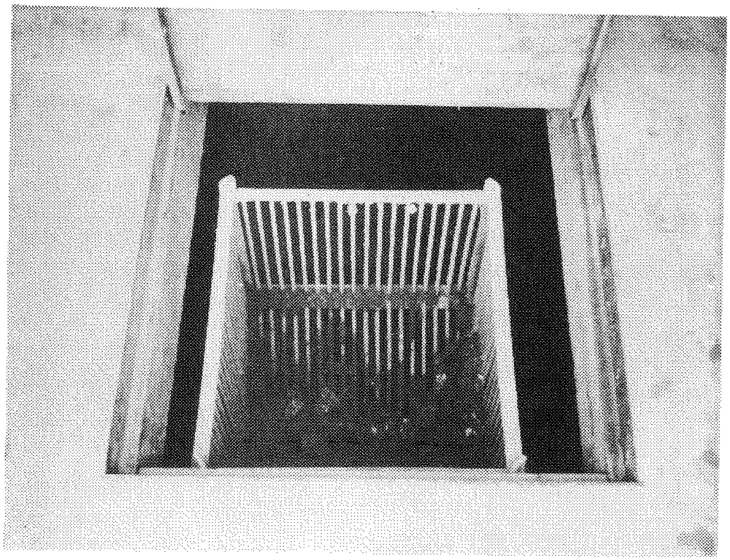


Figure 4.13 Basket for removal of screenings from septage at Slattum Treatment Plant, Norway

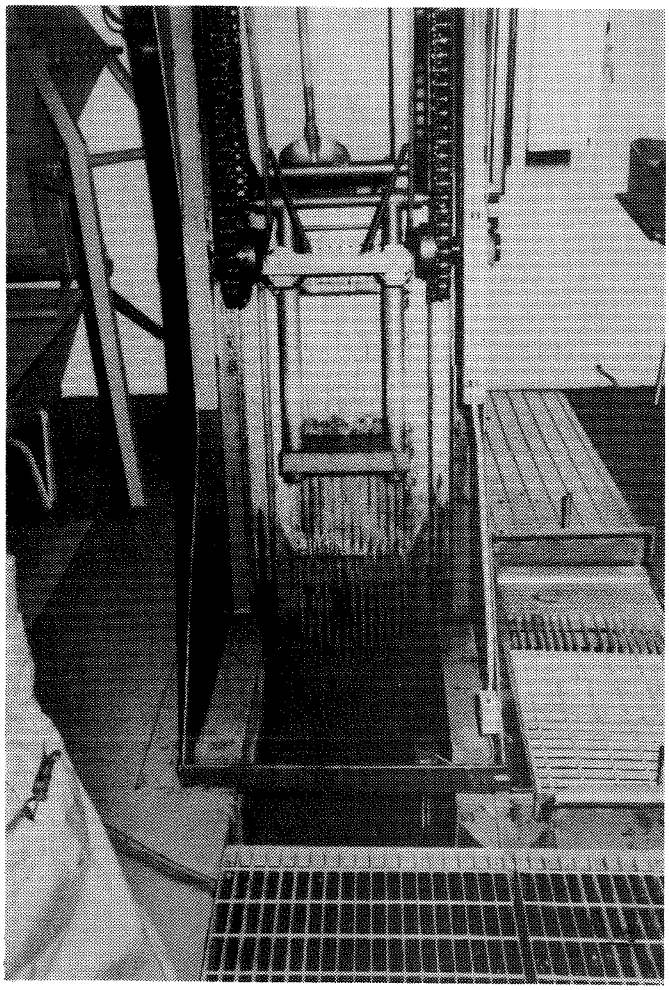


Figure 4.14 Mechanically cleaned bar screen at Dokka Treatment Plant, Norway.

It is important to design the septage inlet so that the flow through the screen is as uniform as possible. In order to achieve this, a short channel must be constructed in front of the screen. Otherwise the truck may pump the septage directly onto the screen and forcing too much material through the openings (see Figure 4.12). This can create operational problems in the plant because of rags etc. entering the unit processes downstream from the screen.

The screenings from septage contain water, organic matter, grease and grit in addition to rags, paper, plastic material, and other coarse material, which create handling and disposal problems (see Figure 4.15). By dewatering the screenings, both the volume to dispose of and the odor are reduced.

Different types of dewatering units are manufactured. Smaller treatment plants receiving septage most often use a drained screw conveyor to transport screening from the bar screen to a container for disposal (see Figure 4.16). Presses designed for dewatering screenings are also commercially available. These presses have been used quite successfully on material from screens handling septage.

GRIT REMOVAL

It is quite difficult to separate grit from septage. Grit in this kind of material is enmeshed in organic matter and grease. Only the most heavy fraction of the sand is easily removed. Lighter fractions will often pass through the grit removal unit. Due to this consideration, only aerated grit chambers are used in Norway for grit removal from septage.

Horizontal flow grit chambers and grit chambers with centrifugal motion have been found by field survey teams to do poor separation of grit when used for septage. These types will therefore not be discussed further in this report.

The aerated grit chamber is a well known unit used in wastewater treatment. Therefore, general design information for this unit will not be given, but only its application for septage will be discussed.

The experience in Norway shows that after the septage passes the screen, it should flow by gravity into the grit chamber. A pumping step must be avoided, if possible, upstream from the grit chamber, mainly due to impeller destruction from grit.

An aerated grit chamber for septage at Lillehammer Treatment Plant is shown in Figures 4.17, 4.18, and 4.19. The grit chamber has a volume of 55 m^3 and handles a maximum load of approximately 80 m^3 septage per day (see Table 2.6). The detention time is therefore longer than what is ordinarily used for a grit chamber. However, the maximum load on the grit chamber will occur when the largest size tanker truck pumps its content of septage through the pretreatment units. Under these conditions the detention time in the grit chamber must not be less than 30 minutes.

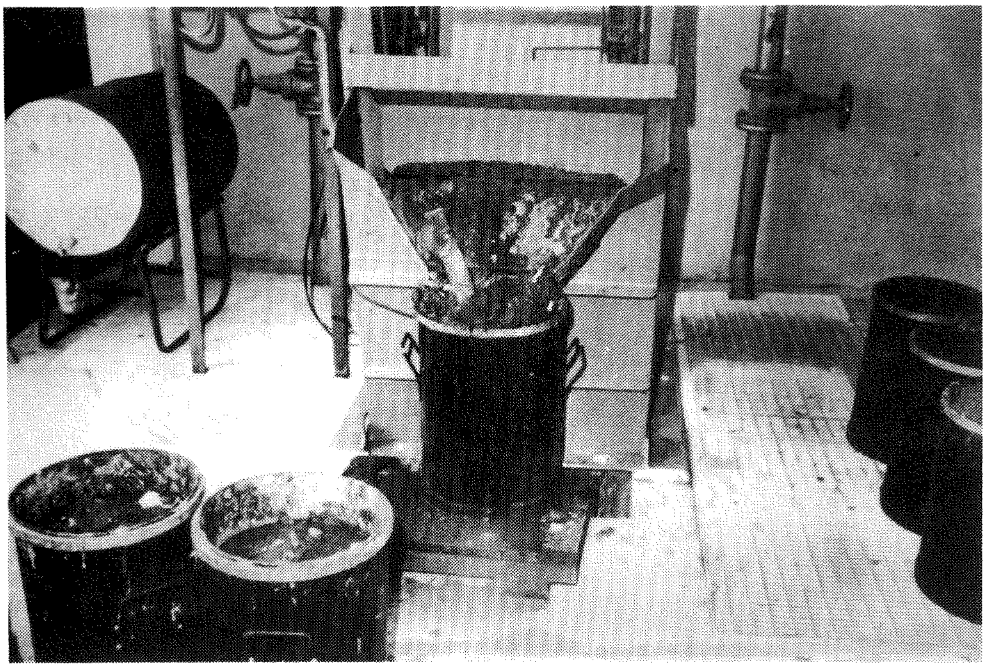


Figure 4.15 Buckets used for collecting material from the screen.

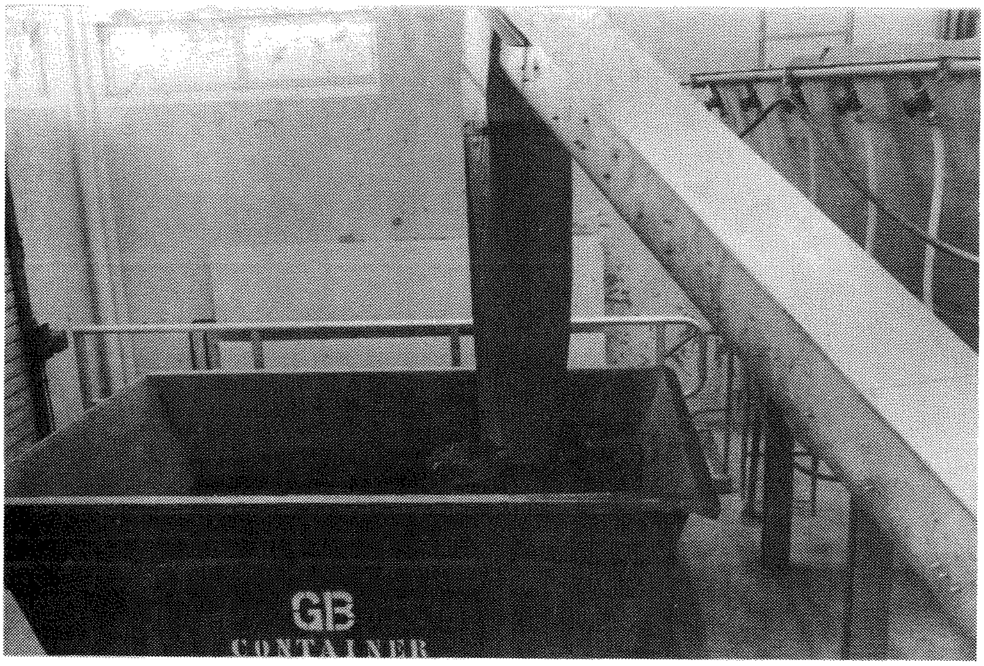


Figure 4.16 Drained screw conveyer used for dewatering material from the screen.

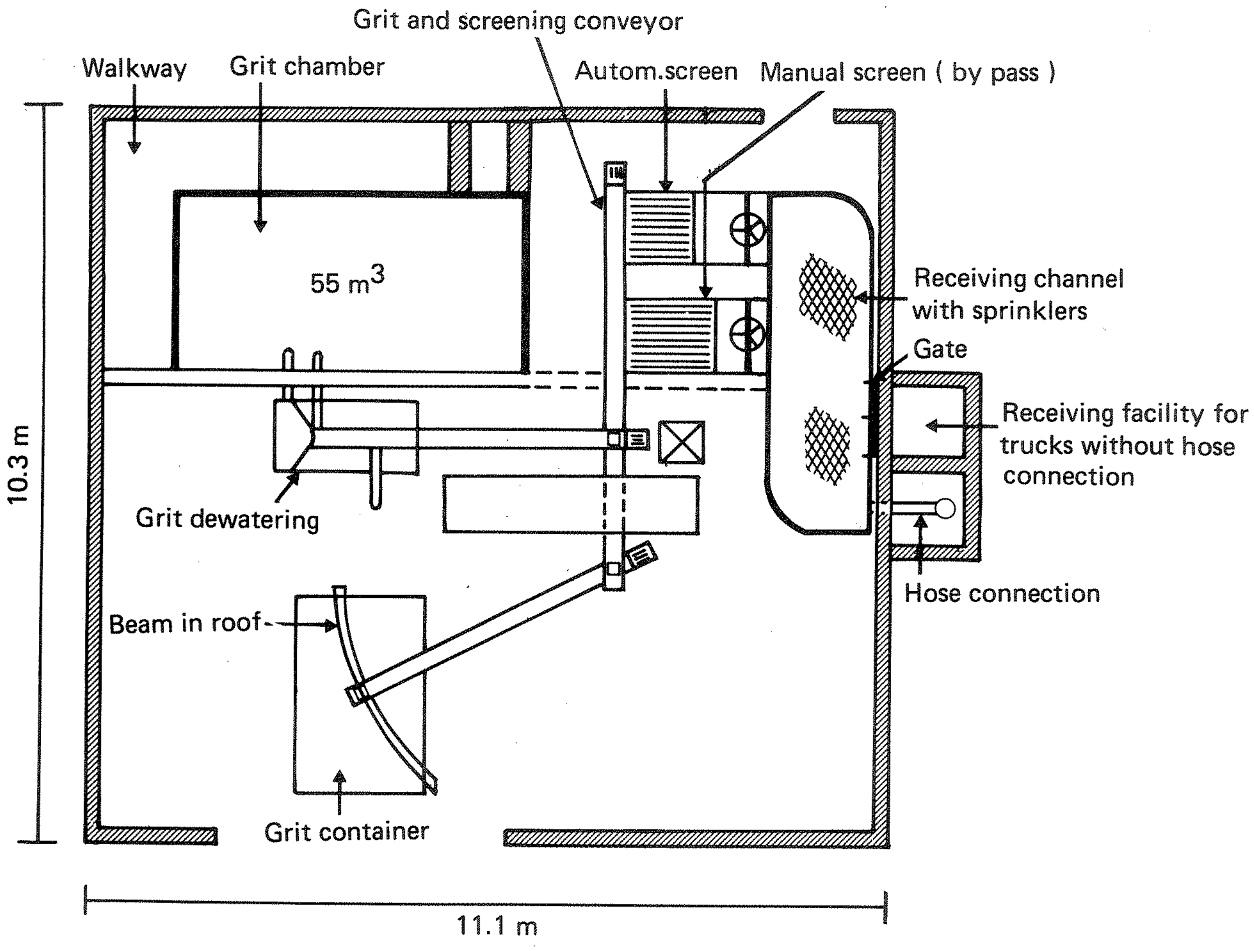


Figure 4.17. Layout of the receiving facility at Lillehammer Treatment Plant, Norway.

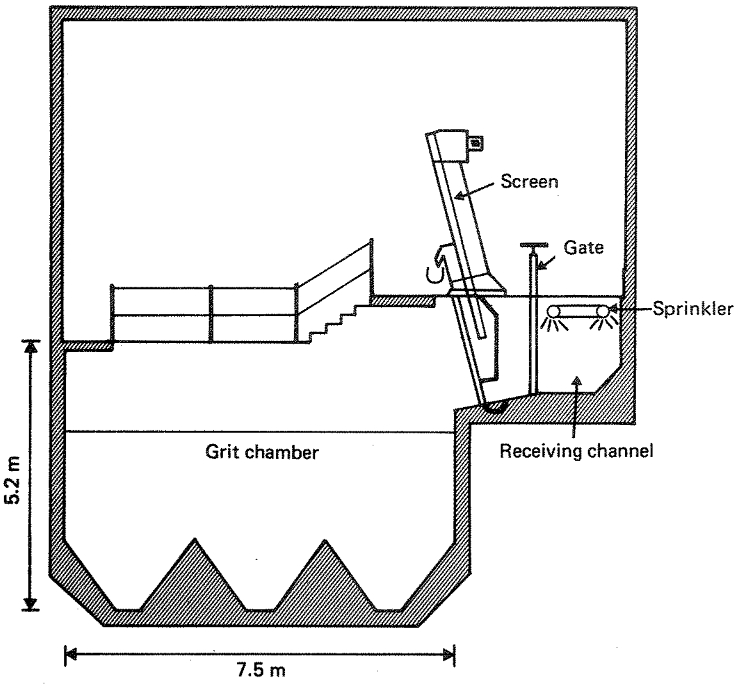


Figure 4.18. Crossection through the grit chamber at Lillehammer Treatment Plant, Norway.

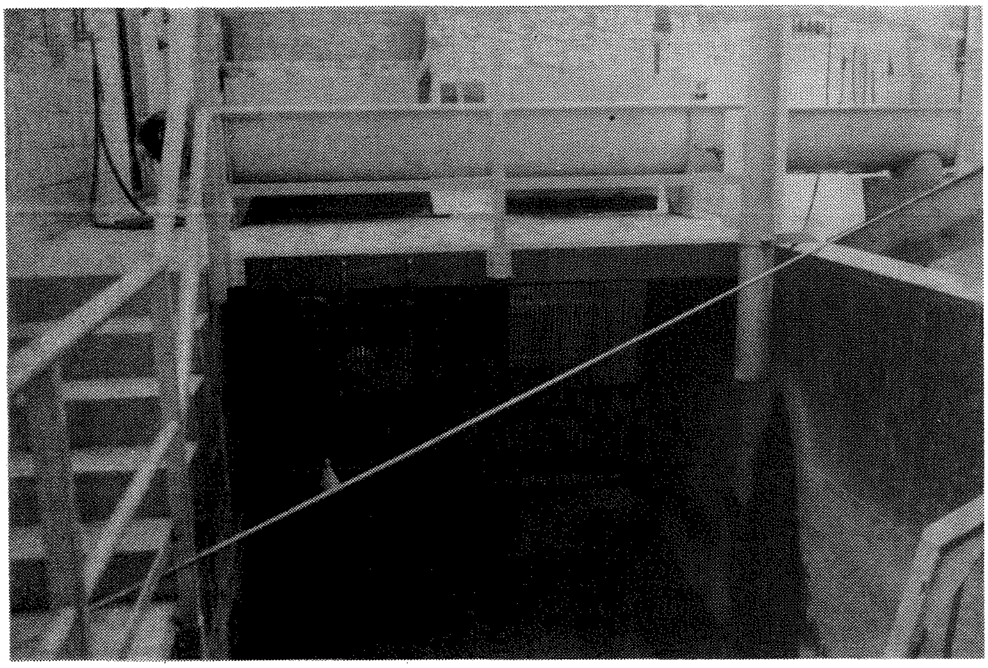


Figure 4.19. Inlet arrangement of grit chamber at Lillehammer Treatment Plant, Norway.

The grit is collected in hoppers at the bottom of the basin. At wastewater treatment plants in Norway air lift pumps, centrifugal pumps, and screw conveyers are used to remove grit. Air lift pumps are not recommended for this use. At Lillehammer Treatment Plant the grit is removed by centrifugal pumps (see Figure 4.17). The grit is then dewatered in a dewatering unit (see Figures 4.20 and 4.21), that consists of a small aerated tank with a dewatering screw that moves the material up an incline, and the water drains back to the tank. The tank is supplied with an overflow that drains back to the grit chamber.

At several plants in Scandinavia the grit chamber has been designed with enough capacity to serve as a combined holding tank and grit chamber. The water level in the tank will vary, depending on the daily routine, with respect to dewatering etc. This is not recommended since the change in water level will automatically change the aeration intensity etc. In Norway it is recommended to transport the grit removed from the septage grit chamber to the grit chamber for wastewater at the treatment plant. Here it will be washed and taken out with the ordinary grit. One must take into account this extra load when designing the grit chamber for wastewater.

REFERENCES

Baumgart, P., (1981), Sammlung, Behandlung, Beseitigung und Verwertung von Schlämmen aus Hauskläranlagen. Technische Universität München (Unpublished).

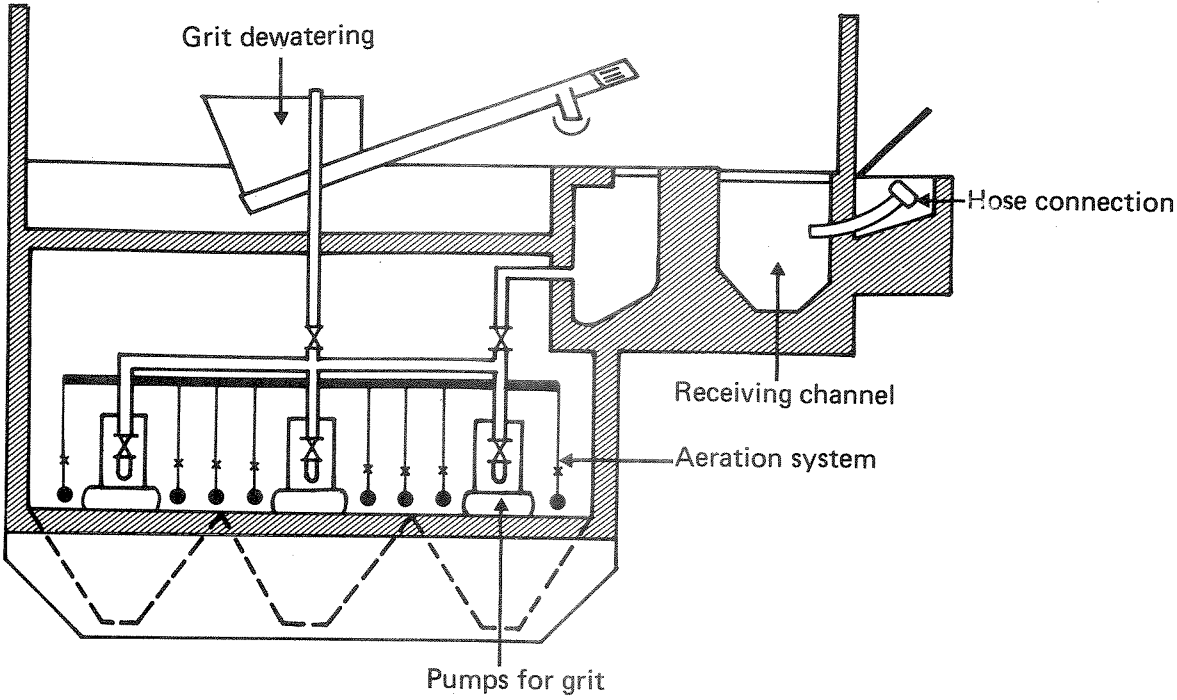


Figure 4.20 The grit is pumped into an aerated grit dewatering unit placed above the grit chamber, at Lillehammer Treatment Plant, Norway.

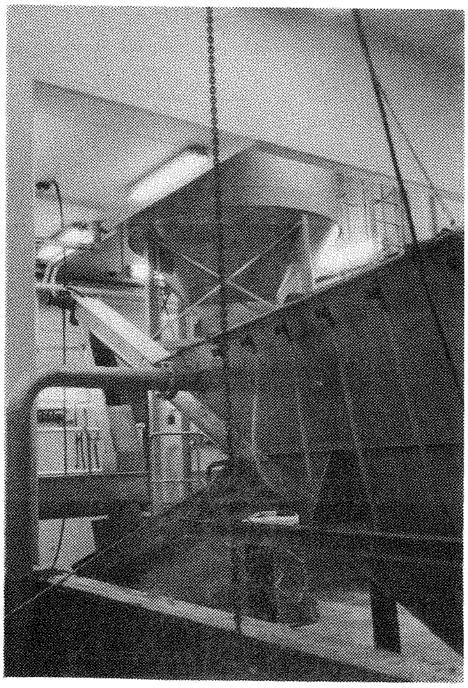


Figure 4.21. Grit dewatering unit at Lillehammer Treatment Plant. Norway.

SECTION 5

SEPTAGE STABILIZATION

GENERAL

In Scandinavia sludge stabilization is considered necessary for two reasons; the final disposal alternatives available require sludge stabilization and the treatment plants are small, necessitating storage before transport for further treatment or disposal elsewhere. To prevent odor -, health -, and hazardous gas problems at the plants, biological or chemical means of stabilization are usually employed. In Norway anaerobic treatment is usually not feasible because of high construction cost when used at small plants. This is not true in the other Scandinavian or in Central European countries.

Anaerobic and aerobic stabilization can be compared in many ways; both processes stabilize septage by breaking down the organic material. Chemical stabilization with lime does not reduce the organic material in the sludge or result in permanent stabilization; only a prolongation of the time required before microbial break-down takes place can be expected. However, in many cases temporary stabilization is sufficient before removal or disposal, and lime stabilization is therefore favored at several treatment plants in Norway, where septage is treated at municipal treatment plants. This is not true in other European countries.

ANAEROBIC DIGESTION OF SEPTAGE

Septage can be stabilized by anaerobic digestion. Considering the characteristics of septage (see Section 3), this is to be expected. However, in many cases septage is fed to digesters that treat other types of sludges as well (primary and/or biological sludges). It is therefore of interest to know what influence septage received at a municipal plant will have on digester performance.

Baumgart (1981) studied the influence of septage on digester performance. Different quantities of septage were added with the primary sludge in pilot digesters run at 33 °C. Table 5.1 shows the result obtained. Baumgart concludes that with an increase in organic loading the BOD_5 removal in the supernatant decreased, but the COD in the same supernatant stayed nearly constant. In Germany the degree of sludge stability is measured by the content of organic acids (measured as mg/l acetic acid). Baumgart found that even with detention times less than 10 days in the digester the digested septage met the requirements for sludge stability. A fully anaerobically stabilized sludge must not have an organic acid content exceeding 300 mg/l, as acetic acid.

TABLE 5.1. ANAEROBIC STABILIZATION OF PRIMARY SLUDGE WITH SEPTAGE ADDITION (Baumgart, 1981).

Test	Primary sludge	Septage	Organic loading	Untreated Sludge			Digested Sludge					
				VS	BOD_5	COD	VS	BOD_5	BOD_5 Filtrate	COD	COD Filtrate	organic acids
No.	l/d	l/d	$kg/m^3.d$	kg/m^3	mg/l	mg/l	kg/m^3	mg/l	mg/l	mg/l	mg/l	mg/l
1.1	23.5	1.5	1.21	24.18	9 130	29 520	12.20	2 250	425	18 420	7 390	234
2.1	25	-	1.28	25.66	9 650	31 240	12.89	2 170	378	22 820	6 960	144
1.2	20	5	1.10	21.81	10 110	32 970	14.27	3 330	484	20 720	3 200	217
2.2	25	-	1.30	25.99	11 950	38 040	15.64	3 320	324	23 070	4 200	170
1.3	20	6 - 25	0.98	13.80	5 790	23 050	13.15	2 370	315	19 820	2 240	109
2.3 1)	25	-	0.95	19.04	7 280	28 650	15.06	2 410	340	23 320	2 400	92
1.4	-	30 - 60	1.66	19.22	7 070	35 670	13.57	3 350	475	29 690	4 350	197
2.4	25-50	-	1.91	25.64	8 420	33 550	16.62	3 010	394	22 160	4 030	172
1.5	25	0 - 15	1.28	22.69	10 000	30 900	15.22	4 340	623	25 700	1 970	276
2.5	25	-	1.26	25.18	10 100	33 780	17.80	2 810	480	18 240	2 380	102

1) Thermophilic stabilization.

In Japan studies on anaerobic digestion of "night soil" have been made (Matsumoto et al., 1964; Iwai et al., 1962). In the mesophilic temperature range Matsumoto and Endo varied the temperature between 30 and 45 °C and the detention time between 5 and 30 days. The highest gas production was found to be between 550 and 570 l/kg VS at 37 °C and 20 days detention time. The lowest values for organic acid (99 mg/l) and the BOD_5 in the sludge liquor (840 mg/l) were found at 33 °C and 30 days detention time. It was proposed by Matsumoto and Endo (1964) to use 33 °C and 20 days detention time for full scale design. Iwai et al. (1962) suggest 30 days detention time and digester temperature of 30 °C. In order to optimize the digestion process, Iwai let the "night soil" thicken for two hours and fed the lower 1/4 volume to the digester, and the rest was treated in a municipal treatment plant.

Baumgart (1981) studied also thermophilic anaerobic stabilization of septage (series 2.3 in Table 5.1). He experienced operational problems during the series of experiments. However, he points out the advantages with thermophilic stabilization:

Shorter detention time
Higher gas production
Better pathogen kill.

The conclusions given by Baumgart were only partly confirmed by Matsumoto et al. (1964) who agreed that better pathogen kill can be achieved at higher temperatures, but the gas production was lower in the thermophilic range than in the mesophilic range (detention time was constant). The sludge properties and the degree of stability deteriorated at higher temperatures.

The European experience is that septage can be stabilized anaerobically, but the sludge characteristics (e.g. VSS, grease) have to be taken into account when designing the digester. It is also important to give the sludge the necessary pretreatment (sand and grit removal) in order to avoid operational problems.

LIME STABILIZATION OF SEPTAGE

In many cases temporary stabilization is sufficient, and lime stabilization is therefore used at several treatment plants receiving septage. The reason for this is that the great variations in the volume of septage received will make lime stabilization advantageous over anaerobic or aerobic processes.

Much work has been carried out on lime stabilization of sewage sludges, including septage. Attention has been given to the theory behind lime stabilization, the necessary lime addition to stabilize the sludge, inactivation of pathogenic organisms and what effect lime stabilization has on dewatering properties of sludges. These aspects of lime stabilization will be discussed, as well as some of the practical aspects when using lime stabilization at a municipal treatment plant receiving septage.

Change of pH in Sludges due to Lime Addition

Work done at NIVA (Paulsrud & Eikum, 1975) determined the quantity of lime necessary to increase the pH to 11.0 for different types of sludges. However, the increase in pH of different types of sludges to pH 11.0 does not disclose the dosage necessary to keep the pH above a certain value for a given period. Tests indicated that the dosages necessary to raise the pH to 10.0, 10.5, and 11.5 for different types of sludges were not sufficient to keep a high pH during storage. These tests also indicated that the storage temperature is important in determining the rate of fall of pH. All the sludges except the alum sludge underwent a pH reduction of 1-3 pH units in 24 hr storage. Figure 5.1 shows the pH vs. storage period and lime dose for septage.

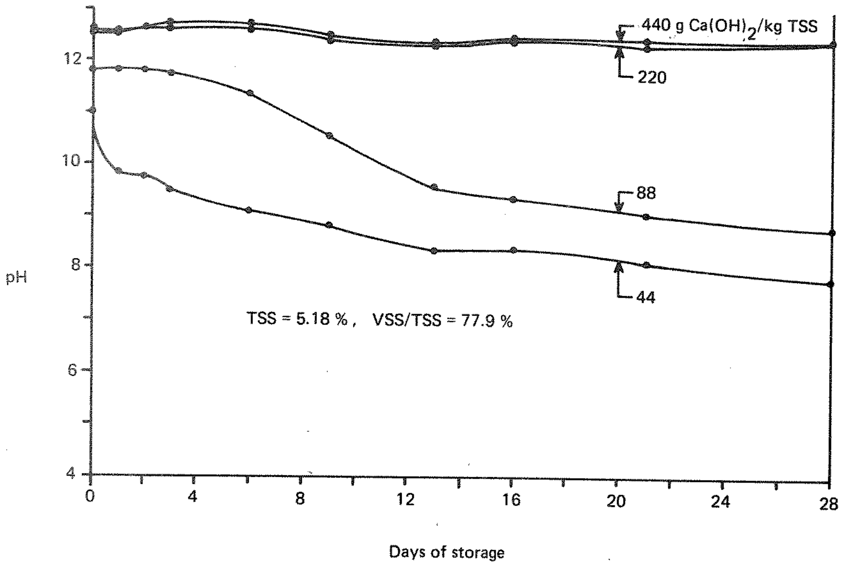


Figure 5.1. Change in pH of septage during storage at 20 °C using different lime dosages (Paulsrud et al., 1975).

The lime dosages necessary to prevent pH reduction and the production of odors within 14 days are given in Table 5.2.

Change in Intensity and Type of Odor from Septage when Adding Lime

During storage of lime stabilized septage it was noticed that as soon as pH fell below 11.0, the odor increased considerably. This confirms an observation reported by Buzzell et al. (1967).

During storage of lime-stabilized septage an increase in odor intensity index is normally experienced regardless of the amount of lime added (Eikum et al., 1974). The increase usually takes place during the first 8 days of storage. The odor intensity then remains fairly constant during the rest of the storage period (see Figure 5.2). Based on this result, using the ASTM - D1292 method for measuring OII (odor intensity index), there is no reduction of OII which occurs during lime stabilization of septage.

The intensity of odors from sludges is important, but the type of odor must be considered as well. Lime added to a particular sludge will transform the rotten offensive smell usually associated with raw sludges to an ammonia or manure odor. The odor after lime addition is less objectionable than the raw sludge odor.

TABLE 5.2. LIME ADDITION NECESSARY TO KEEP pH > 11 AT LEAST 14 DAYS (20 °C) (Paulsrud & Eikum, 1975)

Type of sludge	Dosage g $Ca(OH)_2$/kg TSS
Primary sludge	100-150
Septage	100-300
Biological sludge$^{1)}$	300-500
Al-sludge (secondary precipitation)$^{2)}$	400-600
Al-sludge (secondary precipitation) + Prim. sludge (TSS_{Al}:TSS_{prim} = 1:1)$^{3)}$	250-400
Fe-sludge (secondary precipitation)	350-600

1) Conventional activated sludge plant.
2) Secondary precipitation:precipitation of primary treated effluent.
3) TSS = Total suspended solids.

The processes that the lime-stabilized septage goes through after lime addition, will undoubtedly change the "nuisance potential" (i.e. release of odorous gases) of the sludge. Also practical experience indicates that dewatered sludge can be stored much longer without causing odor problems than undewatered sludges.

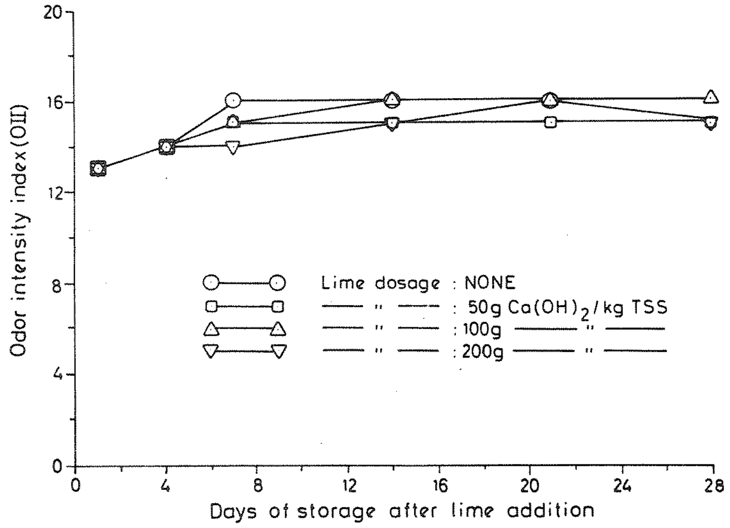


Figure 5.2. Change in odor intensity index (OII) during storage of lime stabilized septage at 20 °C (Eikum et al., 1974).

Survival of Pathogens during Lime Stabilization

Work by Farrell et al. (1974) and Counts et al. (1975) has shown that lime stabilization will reduce pathogens in sludges. However, most work has been based on 24 hr storage after lime addition. Since the stability concept is based on several days of storage after lime addition, it is necessary to look at the removal of pathogens with respect to lime dosage and storage period.

Work done at NIVA, presented in Table 5.3, shows that a reduction of coliforms and fecal streptococci will take place during storage of sludge even without lime addition. However, this is not true for septage. Anaerobic sporeformers were not affected by the storage period alone.

The lowest lime dosage did not reduce the content of the organisms investigated. This was true for all types of sludges tested. The lowest dosage of lime to septage even indicated an increase in the number of organisms in some cases.

The highest lime dosage used during the investigation clearly showed that the content of organisms can be reduced under the detectable limit of 200 organisms per 100 ml. In many cases it took approximately 2 hrs of contact time (0 days storage) to get down to the detectable limit.

Design of Lime Stabilization Processes

Lime stabilization is a very simple process from a design point of view. The only additional unit that has to be constructed, is the basin for mixing the lime with the septage. Figure 5.3 shows the two most commonly used process designs for lime stabilization in Scandinavia. The common practice is to have minimum 15 min. detention time in the mixing basin if the mixing basin precedes a thickener or aerated storage basin. If not, the detention time is increased to 30 min. The mixing is usually achieved by the use of aeration. This is found more effective than the use of mechanical mixing.

Lime can be added to the septage either in a dry form or as a lime slurry. It has been shown that the use of dry lime will increase the lime requirements (Paulsrud, 1973).

Practical Experience from Lime Stabilization at Plants Receiving Septage

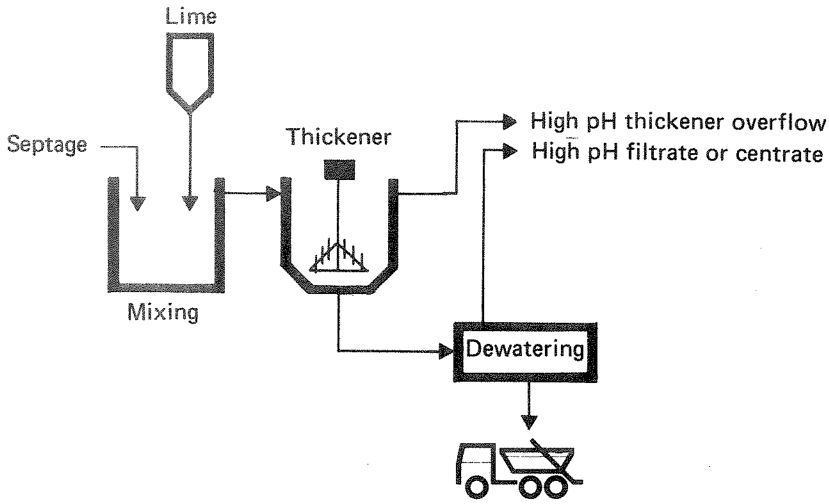
The major reason for using lime stabilization is the low capital cost compared with anaerobic or aerobic stabilization. Although the capital cost of lime stabilization is low, the operational cost can be quite high. In addition, several operational problems have been reported by treatment plant operators. In Norway, these problems were so severe at some plants that the lime stabilization process was stopped altogether. In order to obtain better information about the extent of the problem, it was decided in 1977 to make a survey of all the plants using lime stabilization in Norway. The purpose of the investigation was the following:

TABLE 5.3 REDUCTION OF PATHOGENS DURING LIME STABILIZATION (Paulsrud, 1973).

	Days after lime addition at 20 °C	Organisms per 100 ml sludge											
		Primary			Septage			Prim-Chem (Al)			Biol-Chem (Al)		
		Lime dosage $gCa(OH)_2/kgSS$			Lime dosage $gCa(OH)_2/kgSS$			Lime dosage $gCa(OH)_2/kgSS$			Lime dosage $gCa(OH)_2/kgSS$		
		0	50	200	0	50	200	0	150	500	0	200	600
Total coliforms 37 °C	0	$5,6\cdot10^7$	$2\cdot10^7$	$8\cdot10^2$	$3,5\cdot10^7$	$>1,1\cdot10^6$	ND	$4,6\cdot10^7$	$5,6\cdot10^6$	ND	$1,6\cdot10^7$	$2\cdot10^2$	ND
	4	$9,4\cdot10^5$	$>1,4\cdot10^9$	ND	$5,2\cdot10^6$	$>1,4\cdot10^9$	ND	$5,5\cdot10^6$	$1,7\cdot10^7$	ND	$4,9\cdot10^6$	$1,7\cdot10^5$	ND
	7	$6\cdot10^4$	$>9,2\cdot10^8$	ND	$4,4\cdot10^6$	$>2\cdot10^9$	ND	$1,2\cdot10^6$	$2,5\cdot10^8$	ND	$1\cdot10^6$	$1\cdot10^3$	ND
	14	$1\cdot10^3$	$4,5\cdot10^7$	ND	$2,5\cdot10^6$	$2,5\cdot10^7$	ND	$9,5\cdot10^4$	$2,5\cdot10^8$	ND	$1,2\cdot10^5$	$8,5\cdot10^4$	ND
	28	$6\cdot10^2$	$>1,1\cdot10^8$	ND	$8,9\cdot10^7$	$3,9\cdot10^7$	ND	$1,7\cdot10^4$	$1,9\cdot10^7$	ND	$6,6\cdot10^4$	$3,9\cdot10^5$	ND
Fecal coliforms 44 °C	0	$2\cdot10^7$	$1,1\cdot10^7$	ND	$3,9\cdot10^6$	$6,2\cdot10^5$	ND	$2,8\cdot10^7$	$2,5\cdot10^5$	ND	$1,8\cdot10^6$	ND	ND
	4	$2,2\cdot10^5$	$>1,2\cdot10^8$	ND	$1,5\cdot10^6$	$4\cdot10^6$	ND	$2,3\cdot10^6$	$5,4\cdot10^5$	ND	$4,1\cdot10^5$	$1,2\cdot10^5$	ND
	7	$1\cdot10^4$	$>6\cdot10^7$	ND	$3,3\cdot10^5$	$>7,2\cdot10^7$	ND	$8\cdot10^4$	$3,4\cdot10^7$	ND	$8\cdot10^4$	$1\cdot10^3$	ND
	14	ND	$2,5\cdot10^7$	ND	$2,4\cdot10^6$	$2,4\cdot10^6$	ND	$6,1\cdot10^4$	$2,2\cdot10^7$	ND	$9\cdot10^3$	$5\cdot10^2$	ND
	28	ND	$2,3\cdot10^7$	ND	$1\cdot10^7$	$1\cdot10^7$	ND	$1,2\cdot10^4$	$8\cdot10^6$	ND	$6,5\cdot10^4$	$2\cdot10^2$	ND
Fecal streptococcus	0	$1,1\cdot10^6$	$2,5\cdot10^6$	$4\cdot10^2$	$4,7\cdot10^3$	$3\cdot10^5$	ND	$2,7\cdot10^6$	$2,2\cdot10^6$	ND	$8,7\cdot10^5$	$3,4\cdot10^3$	$2\cdot10^2$
	4	$2,7\cdot10^4$	$>6,6\cdot10^7$	ND	$1,1\cdot10^5$	$>2\cdot10^9$	ND	$4,9\cdot10^5$	$>2,3\cdot10^7$	$3,9\cdot10^4$	$1,4\cdot10^5$	$5\cdot10^4$	$1\cdot10^3$
	7	$7,8\cdot10^4$	$>5,2\cdot10^7$	ND	$1\cdot10^3$	$>2\cdot10^9$	ND	$9,4\cdot10^4$	$3,7\cdot10^7$	ND	$1,2\cdot10^5$	$3,4\cdot10^3$	ND
	14	$1,6\cdot10^4$	$4,4\cdot10^6$	ND	ND	$4,5\cdot10^7$	ND	$2,6\cdot10^4$	$4,7\cdot10^7$	ND	$3,2\cdot10^4$	$2,1\cdot10^4$	ND
	28	$2\cdot10^3$	$3,7\cdot10^5$	ND	$1\cdot10^3$	$5\cdot10^5$	$3\cdot10^3$	$4\cdot10^2$	$1,4\cdot10^5$	ND	$6\cdot10^2$	$3,1\cdot10^3$	ND
Anaerobic spore-formers (*Clostridium perfringens*)	0	$3,4\cdot10^5$	$3,1\cdot10^5$	$2\cdot10^4$	$3,3\cdot10^5$	$8,1\cdot10^4$	$2\ 10^2$	$>1\cdot10^4$	$1,1\cdot10^5$	$2,9\cdot10^5$	$2,5\cdot10^5$	$1\cdot10^5$	$2,1\cdot10^4$
	4	$2,4\cdot10^5$	$4,6\cdot10^5$	ND	$2,8\cdot10^5$	$8,3\cdot10^5$	ND	$1,4\cdot10^5$	$1,8\cdot10^5$	ND	$1,6\cdot10^5$	$3\cdot10^4$	ND
	7	$5,1\cdot10^4$	$3\cdot10^5$	ND	$3,4\cdot10^5$	$3\cdot10^5$	ND	$6,5\cdot10^4$	$>5\cdot10^4$	ND	$>1\cdot10^5$	$3,1\cdot10^5$	ND
	14	$3,5\cdot10^5$	$8\cdot10^5$	ND	$3,4\cdot10^5$	$1,6\cdot10^6$	ND	$1,5\cdot10^5$	$1,8\cdot10^5$	ND	$1,6\cdot10^5$	$5\cdot10^4$	ND
	28	$2,7\cdot10^5$	$6,6\cdot10^6$	ND	$1\cdot10^6$	$2,8\cdot10^7$	ND	$2,8\cdot10^5$	$2,2\cdot10^5$	ND	$1,8\cdot10^5$	$2,2\cdot10^5$	ND
pH	0	5,40	9,55	12,45	5,65	11,05	12,45	6,40	10,45	12,55	6,30	11,30	12,55
	4	5,35	6,50	12,50	5,60	8,55	12,55	6,30	9,25	12,50	6,80	10,60	12,55
	7	5,30	6,35	12,45	5,50	7,70	12,50	6,25	8,65	12,40	6,70	10,35	12,50
	14	4,95	5,70	12,35	5,35	6,40	12,40	5,90	8,10	12,45	6,75	10,30	12,55
	28	5,00	5,50	12,35	5,30	5,75	12,40	5,85	7,10	12,45	7,05	9,40	12,55

ND = not detectable (<200/100 ml).

Alternative 1



Alternative 2

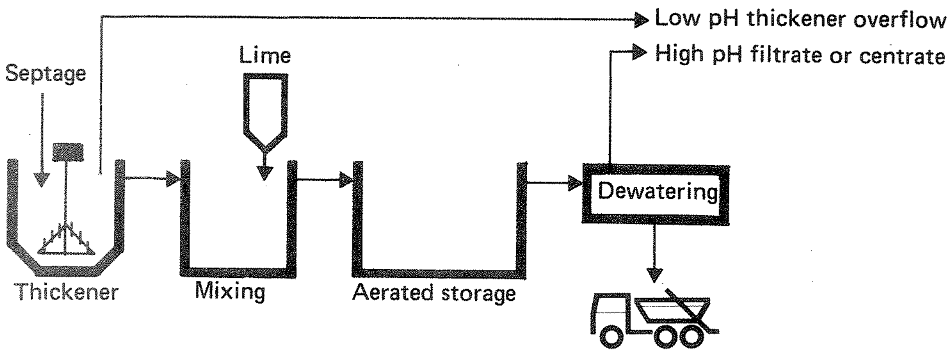


Figure 5.3. The most common process trains used for lime stabilization (Eikum, 1976).

1. Determine what the operational procedures were at the different plants using lime stabilization.
2. Investigate operational problems in connection with the lime storage, feeding, and mixing.
3. Determine what quantities of lime were found necessary for stabilization and measure the sludge stability during storage.
4. Investigate the problems in the treatment plant process due to the recycle of high pH and alkalinity supernatant.
5. Recommend the necessary changes in the design procedure used for lime stabilization.

Table 5.4 presents pertinent data of the wastewater treatment plants that were incorporated in the survey. Almost all plants receive septage. The smallest plant treated waste from approximately 1,400 persons while the largest plant had a design capacity of 52,000 persons. All the plants except Enga Treatment Plant were completely enclosed in a building.

Six of the plants added dry lime by gravity to a screw feeder. Due to a gradual build-up of lime, the screws finally stopped because of the increased resistance against rotation. At one plant the motor was damaged and had to be replaced.

Four of the six plants used a mixing chamber to mix the lime and the sludge. The plants had severe problems with caking and finally clogging of the box outlet. However, this method did not cause any dust problems at the plant.

The six plants that added the lime into an aerated mixing basin, all had problems with lime-sludge deposits on the bottom. This reduced the effective volume of the basins, and these had to be cleaned regularly.

Previous work (Eikum & Paulsrud, 1974) defined a fully stabilized sludge as one that can maintain pH above 11.0 during 14 days of storage at 20 °C in an open beaker. Based on this definition, it was apparent that very few of the plants actually produced stabilized septage. At only three plants was it possible to calculate the lime usage in kg $Ca(OH)_2$ per ton dry solids using the data provided by the treatment plant operator. The rest of the plants did not record the amount of lime used or the amount of sludge processed at the plant.

Only 13 of the plants investigated had dewatering equipment. The sludges from the other plants were trucked to larger plants for dewatering. At 8 of the plants the plant operator had severe problems with dewatering the sludges as soon as the pH in the sludge reached 9.0 or above. An increase in polymer dosage reduced the problem, but did not eliminate it altogether. At only 3 plants did the operators report that the dewaterability of the sludges was independent of the pH in the sludge.

The survey at the existing treatment plants in Norway using lime stabilization gave the following conclusions:

TABLE 5.4 TREATMENT PLANTS USING LIME STABILIZATION IN NORWAY (Paulsrud and Eikum, 1977).

No.	Name of plant	Design flow		Actual load	Primary	Prim. prec.	Second prec.	Biol.-Chem.	Constructed year	Plant receive septage
		Persons	Flow (m^3/h)	Persons						
1	Aursmoen	2500	52	ca.1000			X		-75	-
2	Maura	2500	52	-			X		-75	-
3	Harestua	2500	52	ca. 750			X		-74	-
4	Bjørkelangen	2500	52	" 1500			X		-75	X
5	Nannestad	2500	52	" 1000			X		-74	X
6	Gjerdrum	2500	52	" 600			X		-75	X
7	Kløfta	4500	106	" 2500			X		-74	X
8	Jessheim	10000	290	" 7500			X		-74	X
9	Barlidalen	15000	340	" 2500			X		-76	X
10	Brumunddal	8000	216	" 6400				X	-75	X
11	Moelv	5000	105	" 1500			X		-75	X
12	Nesbyen	2250	42.5	" 2000		X			-75	X
13	Hov	3000	85	" 1000			X		-76	X
14	Kongsvinger	14000	300	" 5000			X		-76	X
15	Loe Bruk	10000	180	" 700		X			-77	X
16	Enga	52000	1280	" 6500	X				-76	X
17	Rambekk	25000	750	" 6000			X		-75	X
18	Bjørkelia	2000	45	" 1500		X			-74	-1)
19	Beitostølen	2000	37.5	" 1000				X	-73	-
20	Rotnes	10000	200	" 5000			X		-76	X
21	Breiskallen	10000	410	" 300			X		-77	X
22	Seljord	1400	40	-		X			-76	X2)
23	Brandbu	7000	175	" 4000				X	-74	X2)

1) Lime precipitation plant

2) Lime stabilization of septage only.

1. The plant operators did not add enough lime to the sludge to produce a truly lime-stabilized sludge. (pH > 11.0 during 14 days of storage at 20 °C.)
2. The major operational problem was moisture entering the lime-feed equipment and thus causing this to clog. Frequent cleaning partly eliminated this problem.
3. Treatment plants with alum precipitation should always be equipped with a retention basin for lime supernatant return to even out the increased alum demand of this stream.
4. Plant operators reported that lime stabilization reduced odor problems associated with septage handling at the plant, even if the amount of lime added was below the necessary dosage to produce a truly lime-stabilized sludge.

AEROBIC STABILIZATION OF SEPTAGE

Aerobic stabilization is widely used for sludge stabilization at small wastewater treatment plants. The process is easy to operate and produces a stable end product.

Aerobic stabilization is a well known process. The discussion will therefore be limited to information regarding stabilization of septage alone or mixed with the treatment plant sludges. However, it is important to be aware of the objectives of the stabilizing process concerning odor potential, supernatant quality, etc.

Influence of Aerobic Stabilization on Odor Intensity of Septage

Odorous gases are produced through biological breakdown of organic material. The most common cause of odors is hydrogensulfide H_2S, and the conditions that lead to H_2S production also favor the production of other odorous organic compounds. These compounds include mercaptans, indoles, skatoles, and other nitrogen- and sulphur-bearing compounds (Dague, 1972).

Strong offensive gases from raw sludges will disappear during the first stage of the stabilization process. Figure 5.4 shows that septage with a strong offensive odor prior to stabilization has a rapid decrease in odor intensity during the first few days of aeration. During the following aeration period only slight changes in odor intensity will take place. This is in agreement with practical experience since aerobic stabilization usually does not create offensive odors at the plant.

However, it is not necessarily the odor of the sludge in the aerobic digester that is of concern, but whether or not odor problems occur during handling and storage of the sludge after stabilization. Usually the odor intensity of sludges will increase during storage, but the total increase will depend on the number of days the sludge has been aerated.

This is also true for septage, although the odor intensity of untreated septage decreases during storage rather than increase. It must be recognized, though, that the odor of septage is usually extremely offensive (OII = 20) when it is discharged at a wastewater treatment plant. Even if a reduction in odor intensity occurs during storage alone, the odor is still strong.

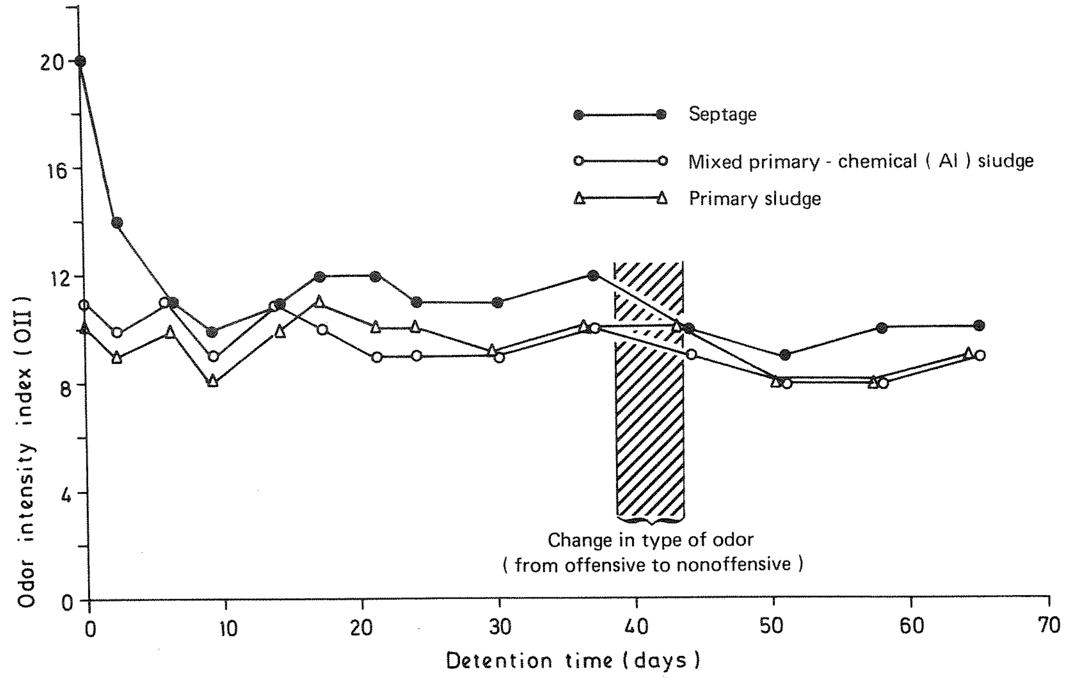


Figure 5.4 Change in odor intensity index (OII) vs. detention time during aerobic stabilization at 19 °C (Eikum et al., 1977).

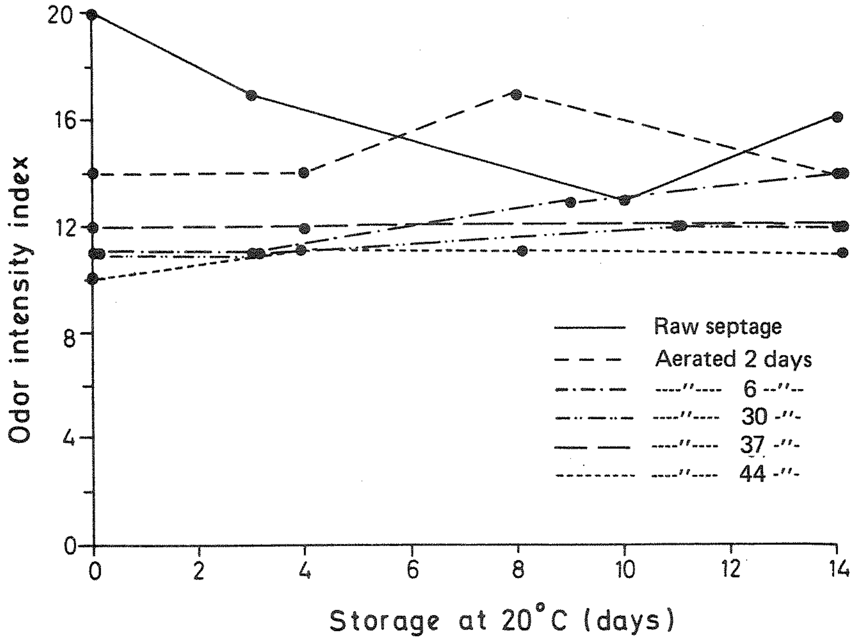


Figure 5.5 Odor intensity index (OII) vs. storage period, septage (Eikum et al., 1977).

In Figure 5.5 it can be seen that when septage is aerated for a short period, it will increase in odor intensity during storage, while the same septage will not change its odor intensity during storage if the detention time in the digester is sufficiently long.

Eikum et al. (1977) stated that the following requirements regarding odor should be met before an aerobically stabilized sludge can be considered as a fully stabilized sludge:

> The Odor Intensity Index (ASTM D 1292) should not exceed 11 at any time during 14 days of storage at 20 °C, unless the odor can clearly be classified as a typical "soil" odor.

Sludge is quite often stored at small treatment plants in Scandinavia before being trucked to a centrally located dewatering station or directly to a sanitary landfill, thus, odors created during the storage period are of prime importance.

Change in Oxygen Uptake Rate during Aerobic Stabilization of Septage

Several factors influence the oxygen uptake rate measured during aerobic stabilization. The most important ones are:

A. Sludge characteristics (VSS, stc.)
B. Temperature during the process
C. Operational strategy of the aerobic digester
D. Microbial composition of the sludge
E. Procedure used when measuring oxygen uptake rate.

The oxygen uptake rate during aerobic stabilization of septage will decrease with increasing detention time in excess of about nine days in the aerobic digester. This is illustrated in Figure 5.6. The oxygen uptake rate is a very useful parameter for digester control. Eikum et al. (1977) found that at 18 °C the septage was fully stabilized if the oxygen uptake rate was $\lessapprox 0.7$ mg O_2/g VSS.hr (based on the definition of stabilized sludge mentioned in the above paragraph.)

Design of Aerobic Stabilization Units for Septage

We will not discuss in detail the design criteria for aerobic stabilization units since this is discussed elsewhere. The stabilization basins, aeration equipment, equipment for supernatant withdrawal, etc. used for septage will be the same when stabilizing other types of sludges. However, the sizing of the units will be different for different types of sludges. Figure 5.7 gives the necessary solids retention time in the aerobic digester for different sludges. Septage and primary sludge need a longer detention time than biological sludges. In Norway, the temperature used for design is usually 15 °C, and the necessary retention time for the septage solids would then be 23 days. (See Figure 5.7.)

The solids retention time and hydraulic detention time are not necessarily the same in an aerobic digester. At most treatment plants aerobic digesters are operated in a semi-continuous fashion; the supernatant is withdrawn from

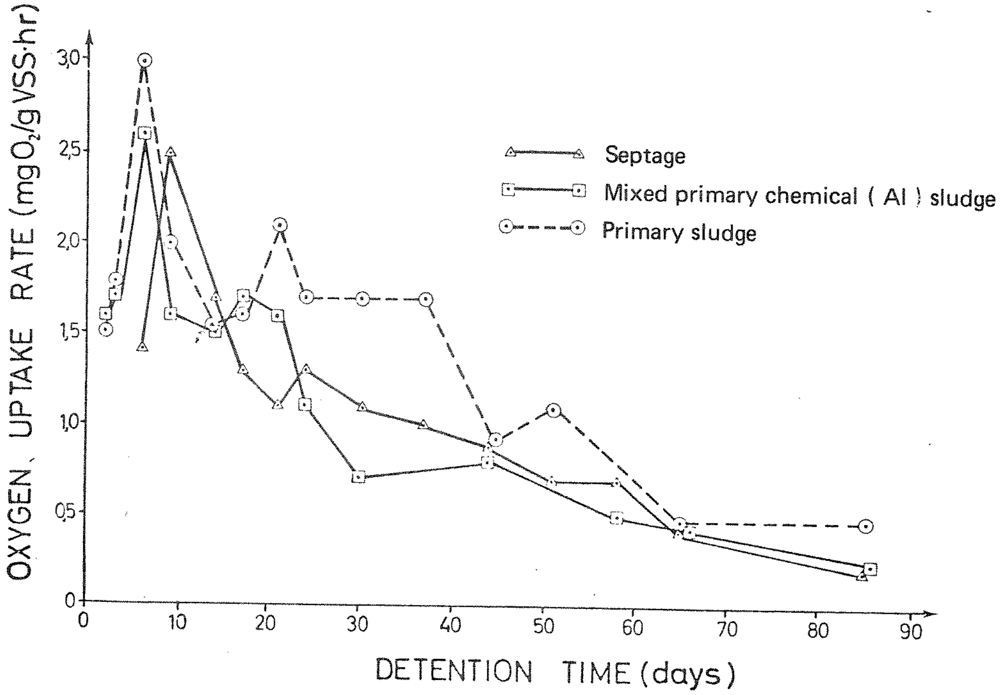


Figure 5.6 Oxygen uptake rate vs. detention time in aerobic digester (Eikum and Paulsrud, 1977).

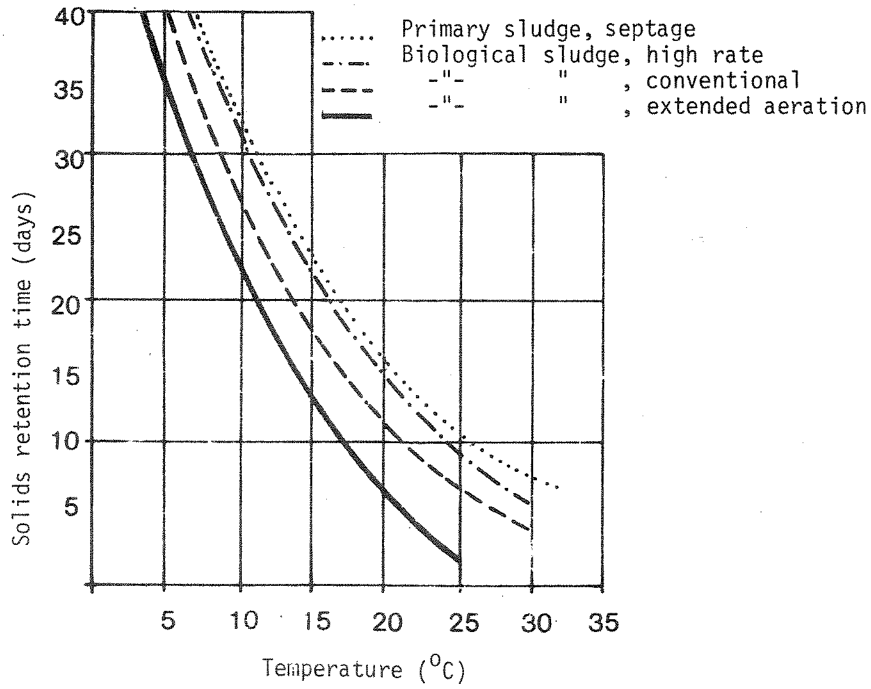


Figure 5.7 Solids retention time vs. temperature in aerobic digester (Eikum and Paulsrud, 1976).

the unit once or twice a day and new sludge is added. Stabilized sludge, however may only be withdrawn from the digester once a week, depending on how well the sludge will thicken in the digester. In Norway, experience has shown that in periods with low digester temperature (winter) it is difficult to achieve efficient solids/liquid separation. In other words, the volume of the supernatant that the operator can withdraw, is very low.

The aeration equipment must be able to supply enough oxygen to have aerobic conditions at all times. Experience has shown that when new septage is added to an aerobic digester, the oxygen concentration in the digester drops. This is expected, but the oxygenation capacity must be sufficient to prevent a period with oxygen deficiency. Table 5.5 gives the necessary air requirements for aerobic digestion of various types of sludges, including septage.

TABLE 5.5. AIR REQUIREMENTS IN AEROBIC DIGESTERS
(Eikum & Paulsrud, 1976)

Type of sludge	Air requirement ($1/min$ per m^3 tank volume)
Primary sludge	60 - 80
Primary-chemical (Al or Fe sludge)	60 - 80
Biological sludge	40 - 60
Septage	80 - 100

The air requirements should ideally be based on oxygen uptake rate measurements. However, when stabilizing septage, the necessary air requirement based on oxygen uptake rate is not sufficient to keep the solids in suspension. The air requirements for septage is therefore higher than for other types of sludges.

Practical Experience from Aerobic Stabilization of Septage

Brandbu Treatment Plant is a biological-chemical treatment plant serving a population of 3000 persons; the design capacity is 7000 persons. The plant is completely enclosed in a building (see Figure 5.8) to prevent operational problems due to freezing during the winter.

The septage enters the sludge treatment facility and undergoes pretreatment (screen and grit chamber) before entering the aerobic digesters. Both the treatment plant sludge and the septage are stabilized, but in separate basins. The total aerobic digester volume used for septage is 165 m^3. This does not include the volume of the aerated sludge holding tank (see Figure 5.9).

In June and July 1976 an investigation was carried out to determine the effect of aerobic stabilization of septage. The amount of septage treated at the plant during that period is shown in Figure 5.10. The septage volumes varied between 0 and 31 m^3/day with an average value of 9.9 m^3/day. Since the daily volume of septage varies considerably, it is very easy to overload the

Figure 5.8 Brandbu Treatment Plant, Norway.

digester one or several days in a row. The result would then be that only partly stabilized sludge would be disposed of.

During the test period the average solids detention time in the aerobic digester for septage was 16.7 days.

The characteristics of the raw septage and the digested sludge are shown in Table 5.6. The percent VSS in the raw septage varied between 58 and 89 percent and in the digested septage between 55 and 64 percent. The digested septage had no offensive odor. The oxygen uptake rate in the digester varied between 1.5 and 3.5 mg O_2/g VSS.hr. This is higher than what is usually found for a fully stabilized septage. It must be recognized, however, that only one truckload of septage into the plant prior to the measurement of the oxygen uptake rate will increase the value of the uptake.

The septage holding tank shown on Figure 5.9 has a volume of 75 m^3. This tank is partly used as a thickener since the aeration system is turned off and the supernatant withdrawn before the stabilized septage is pumped to the dewatering units.

The holding tanks will of course increase the total time of aeration. However, at Brandbu Treatment Plant the aeration system in the holding tank was inefficient.

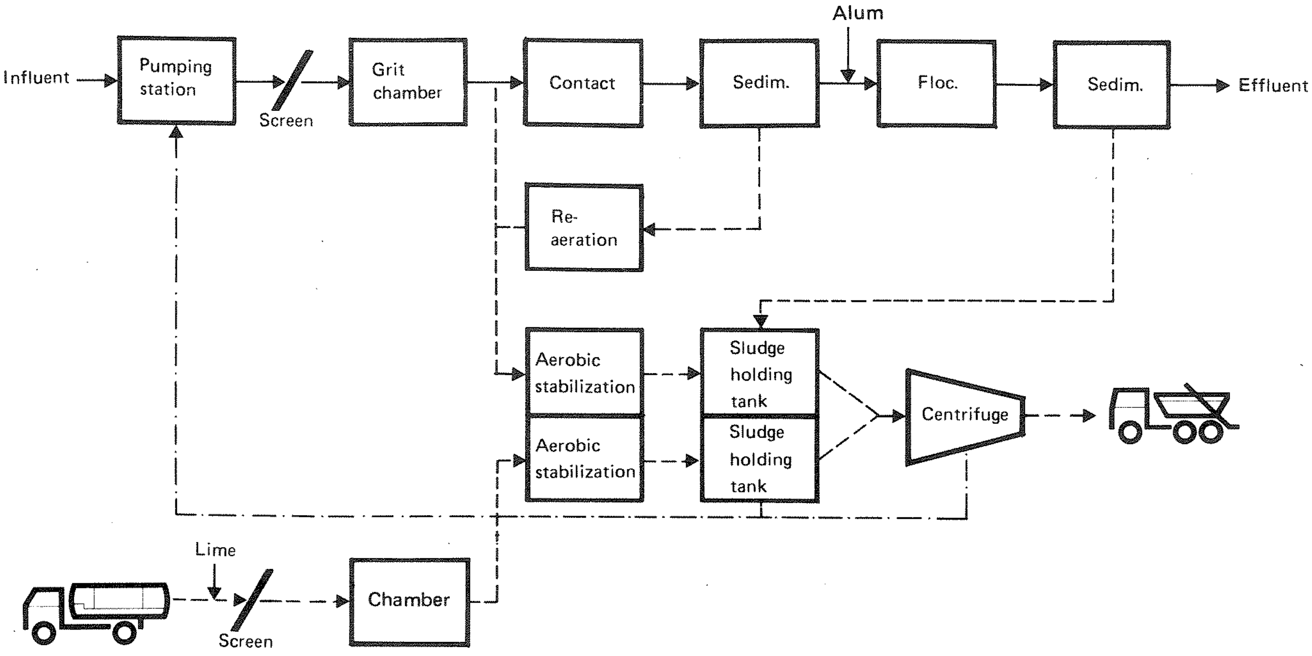


Figure 5.9 Flow diagram Brandbu Treatment Plant, Norway.

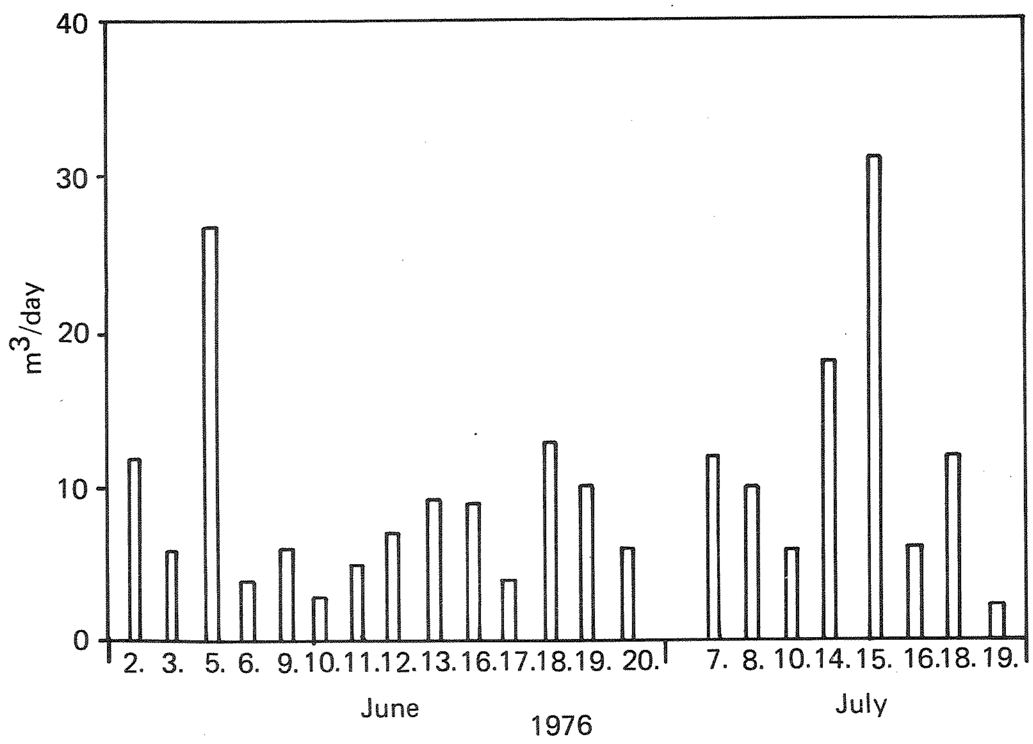


Figure 5.10 Septage volumes received at Brandbu Treatment Plant (Eikum, 1976).

TABLE 5.6 QUALITY OF RAW AND DIGESTED SEPTAGE AT BRANDBU TREATMENT PLANT IN NORWAY (Eikum, 1976).

Raw septage

Date 1975	Temp °C	pH	D.O.* mg/l	SS mg/l	VSS mg/l	$\frac{VSS}{SS}\cdot 100$ %	COD mg O_2/l	Tot-P mg P/l	Tot-N mg N/l
6/9	-	6.4	0.0	16447	13451	82	32128	46	609
6/16	11	6.4	0.0	68478	52089	76	102771	226	2574
6/23	14	7.8	0.0	10822	6245	58	13094	80	333
7/7	13	6,6	0.0	60883	36563	60	88600	333	1363
7/14	-	6,3	0.0	37953	31106	83	84800	284	1170
7/21	-	-	0.0	43650	38690	89	69710	153	1234

Aerobically digested septage

Date 1975	Temp C°	pH	D.O.* mg/l	O_2-uptake rate mg, O_2/g VSS.h	SS mg/l	VSS mg/l	$\frac{VSS}{SS}\cdot 100$ %	COD mg O_2/l	Tot-P mg P/l	Tot-N mg N/l
6/9	20.5	7.8	5.0	3.5	11219	6807	61	8032	86.4	474
6/16	19	8.1	9.1	2.0	10623	6066	57	11309	91.0	315
6/23	19	8.1	8.3	1.5	9769	5353	55	9722	110	308
7/7	21	7.8	4.4	3.4	11951	7634	64	15500	116	391
7/14	21.5	7.9	4.3	-	14095	8585	61	14800	115	343
7/21	22	7.8	2.7	2.6	14800	9330	63	19265	128	593

* D.O. = Dissolved oxygen.

The aerobic digester at Brandbu Treatment Plant works satisfactorily with respect to stabilizing the sludge. The solids retention time is close to the value given in Figure 5.7 at 20 °C. According to the plant operators, no major problems have been experienced with respect to stabilizing septage. Since the study was performed on the digester performance, the practice regarding sludge stabilization has been changed. The biological sludge is presently mixed with the septage prior to stabilization.

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SECTION 6

CONDITIONING AND DEWATERING OF SEPTAGE

FILTERABILITY OF UNCONDITIONED SEPTAGE

The filterability of unconditioned septage has been studied by Løken (1973). The results from specific resistance measurements of 46 septage samples are summarized in Figure 6.1. According to Gale (1971), a specific resistance below 10^{12} m/kg (measured at 49 kPa) is normally required for economic operation of vacuum filters or filter presses. This means that none of the septage samples in Løken's investigation could have been successfully dewatered without conditioning.

CONDITIONING OF SEPTAGE WITH POLYMERS

The conditionability of both untreated and stabilized septage has been studied by using a method developed in the COST-68 project (EUROCOP-COST, 1975). In this test the Capillary Suction Time (CST) of the septage is measured after mixing with water and three dosages of a cationic polymer, Praestol 444K, manufactured by Chemische Fabrik Stockhausen, West Germany. (In addition ferric chloride can be used as a representative of inorganic conditioners.) The CST of each of the sludge samples is measured immediately after mixing the septage with water or the flocculant solution, and again after stirring for fixed periods in a standardized stirrer unit.

When studying conditionability data, both the absolute CST values and their relative changes with increasing stirring time have to be considered. Since the CST values will depend on sludge solids concentration, no definitive limit for proper conditioning can be given; although CST values about 10 seconds with the 18 mm reservoir and below 20 seconds with the 10 mm reservoir are generally recommended after 10 seconds stirring time. In addition, there should be a minor increase in the CST value with increasing stirring time.

The data from untreated septage (Table 6.1) show a relatively high dosage of polymer (about 0.5 percent of TSS) to obtain satisfactory conditioning. The effect of high solids concentration on the CST values is also clearly documented here.

Results from conditioning of aerobically stabilized septage at Brandbu wastewater treatment plant are presented in Table 6.2. The detention time in the digester was 20-25 days during the test period. Compared with the untreated septage (Table 6.1) it is obvious that the aerobic stabilization process enhances the conditionability of the septage. The optimum dosage of Praestol 444K was in the range of 0.125-0.5 percent of total suspended solids. However, pilot scale investigation on short-time aerobic digestion of septage show reduced conditionability with necessary polymer dosages above 0.5 percent of TSS

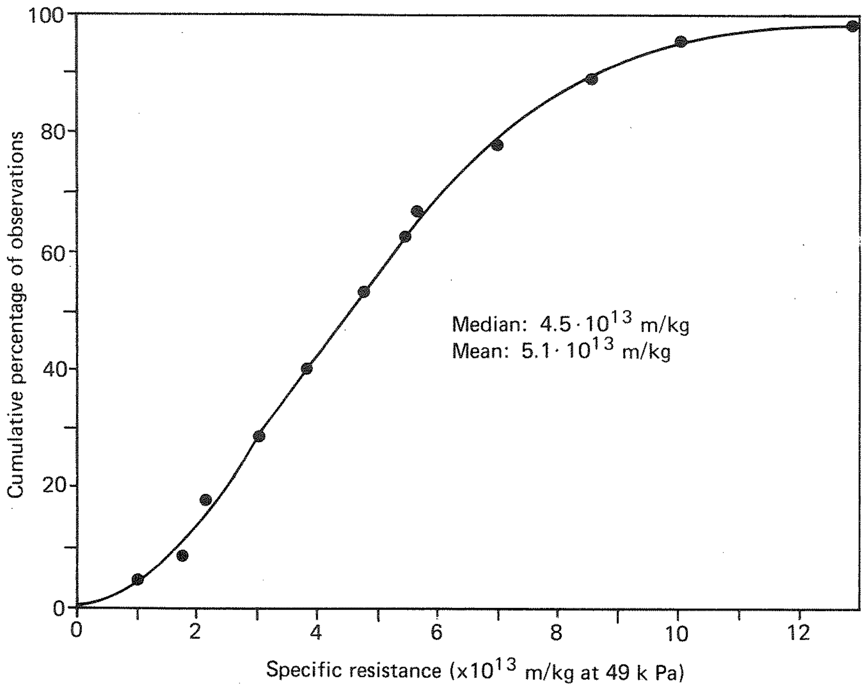

Figure 6.1. Specific resistance of unconditioned septage. (Løken, 1973.)

(see Table 6.3). This is an important factor to consider when planning aerated storage facilities for septage.

In a comprehensive pilot scale study of lime stabilization of wastewater treatment plant sludges (Paulsrud, 1975; Paulsrud & Eikum, 1975; Paulsrud & Eikum, 1977) there was also performed a simplified conditionability test on limed septage. Three different lime dosages were added to a septage sample, and the test was run after six days of storage. The results are given in Table 6.4, and these indicate that an increase in lime dosage gives a slight increase in polymer dosage. Experiences from Rambekk wastewater treatment plant showed, however, much better conditionability of lime stabilized septage (see Table 6.5), and polymer dosages of 0.125-0.25 percent of TSS seemed sufficient. In this full-scale plant the lime addition was also about 100-150 g $Ca(OH)_2$/kg TSS, but the samples for conditionability testing were taken within 1-2 days after lime addition. The shorter storage time probably explains the superior results compared with Table 6.4. This is in agreement with data presented by Paulsrud & Eikum (1977) which showed that conditioning of lime-stabilized sludges requires increasing polymer dosages with increasing storage time of the limed sludge, regardless of the lime dosage used.

CONDITIONING OF SEPTAGE WITH LIME

The effect of lime addition on septage filterability and drainability was studied by Paulsrud & Eikum (1977). The lime dosage varied from 0 to 200 g $Ca(OH)_2$ per kg TSS, and samples were taken throughout a 28 day storage period after lime addition. The changes in pH with increasing lime dosage

TABLE 6.1 CONDITIONING OF UNTREATED SEPTAGE

Sampling date	TSS %	Dosage of Praestol 444K % of TSS	CST with 18 mm reservoir (s)				References
			Stirring time after mixing (s)				
			0	10	40	100	
Aug. 20 1975	12	0 (only water)	483.8	418.4	504.0	375.4	Rambekk wastewater treatment plant (Eikum, 1976)
		0.125	109.6	143.7	276.2	264.2	
		0.25	8.8	35.2	73.4	139.3	
		0.5	-	8.2	15.2	25.3	
Aug. 28 1975	-	0 (only water)	144.5	138.6	135.2	140.3	
		0.125	9.4	10.7	18.4	21.1	
		0.25	8.4	8.8	8.5	12.2	
		0.5	23.6	13.0	7.6	7.9	
Oct. 7 1975	-	0 (only water)	169.9	175.2	177.5	193.6	
		0.125	-	-	-	-	
		0.25	30.1	41.9	73.6	75.1	
		0.5	8.8	12.0	16.7	50.4	
June 9 1976	1.9	0 (only water)	127.3	132.4	121.3	126.8	Brandbu wastewater treatment plant (Eikum, 1976)
		0.125	19.9	47.9	64.4	71.9	
		0.25	7.7	10.5	17.0	29.4	
		0.5	-	6.2	6.1	7.8	
June 16 1976	6.0	0 (only water)	391.2	423.6	403.7	359.6	
		0.125	-	-	-	-	
		0.25	27.7	92.6	146.9	126.9	
		0.5	4.7	7.0	16.2	41.2	
June 23 1976	1.3	0 (only water)	122.5	137.2	142.3	145.1	
		0.125	25.8	42.1	37.4	42.0	
		0.25	12.7	14.4	26.9	41.9	
		0.5	8.9	9.7	10.1	12.3	
July 7 1976	4	0 (only water)	132.7	181.8	196.9	223.8	
		0.125	43.2	64.8	177.1	153.4	
		0.25	9.6	14.8	42.0	78.5	
		0.5	6.5	5.6	10.9	16.5	

TABLE 6.2 CONDITIONING OF AEROBICALLY STABILIZED SEPTAGE (Eikum, 1976).

Sampling point	Sampling date	TSS %	Dosage of Praestol 444K % of TSS	CST with 10 mm reservoir (s)			
				Stirring time after mixing (s)			
				0	10	40	100
Aerobic digester	June 9 1976	1.4	0 (only water)	15.4	16.0	13.9	16.7
			0.125	10.1	-	9.2	13.6
			0.25	9.6	8.4	7.9	11.1
			0.5	14.4	14.5	13.2	9.8
	June 16 1976	1.7	0 (only water)	21.4	19.6	22.0	19.2
			0.125	9.6	10.2	11.6	12.8
			0.25	8.4	9.0	8.1	8.3
			0.5	9.9	-	6.4	9.4
	July 21 1976	2.0	0 (only water)	16.8	16.4	18.7	19.0
			0.125	9.5	9.3	9.1	9.5
			0.25	7.7	8.8	9.6	9.7
			0.5	14.5	10.6	8.9	8.9
Aerated holding tank (after aerobic digestion)	June 16 1976	1.1	0 (only water)	25.8	29.1	27.7	32.2
			0.125	12.2	10.7	10.3	12.8
			0.25	9.2	10.8	11.9	10.6
			0.5	15.7	14.6	13.2	10.2
	June 23 1976	1.3	0 (only water)	20.7	19.1	18.8	20.5
			0.125	7.6	7.7	8.6	9.7
			0.25	6.5	8.0	7.6	8.3
			0.5	11.7	10.5	8.0	8.8
	July 7 1976	1.5	0 (only water)	21.0	21.4	21.7	26.0
			0.125	10.5	11.4	11.9	14.9
			0.25	8.1	9.9	10.1	10.1
			0.5	14.5	8.7	9.5	9.3
	July 21 1976	2.0	0 (only water)	33.7	36.9	41.7	41.0
			0.125	10.0	11.1	12.1	13.4
			0.25	7.9	9.6	9.5	11.2
			0.5	13.8	9.4	6.9	10.8

TABLE 6.3 CONDITIONING OF SEPTAGE FROM SHORT TIME AEROBIC DIGESTION (Eikum, 1976).

Detention time in aerobic digester (days)	Sampling date	Dosage of Praestol 444K % of TSS	CST with 18 mm reservoir (s)			
			Stirring time after mixing (s)			
			0	10	40	100
0 (Untreated septage)	May 28 1975	0 (only water)	166.5	213.5	268.8	250.1
		0.125	11.8	15.7	29.9	46.4
		0.25	6.2	7.5	9.4	14.8
		0.5	10.4	7.6	6.8	7.7
	June 11 1975	0 (only water)	294.0	318.7	313.2	325.7
		0.125	58.5	163.9	211.7	189.1
		0.25	14.1	17.6	35.5	91.5
		0.5	6.5	7.3	-	13.5
	June 24 1975	0 (only water)	-	489.5	453.9	290.5
		0.125	34.6	83.5	115.9	131.3
		0.25	12.5	17.4	36.0	190.5
		0.5	5.6	7.1	10.0	16.5
	July 8 1975	0 (only water)	249.4	226.7	260.7	304.0
		0.125	10.5	18.7	41.4	109.0
		0.25	6.4	8.2	13.6	19.0
		0.5	7.4	4.4	6.6	7.3
1	June 11 1975	0 (only water)	617.1	637.1	732.5	743.1
		0.125	-	-	-	-
		0.25	105.9	266.8	369.9	434.8
		0.5	26.4	30.7	43.7	101.3
	June 24 1975	0 (only water)	491.0	458.7	204.5	353.2
		0.125	-	-	-	-
		0.25	66.8	60.1	105.1	115.0
		0.5	20.2	20.4	27.1	57.3
	July 8 1975	0 (only water)	281.6	352.0	378.9	-
		0.125	16.8	43.9	118.3	200.9
		0.25	9.6	11.6	23.8	34.4
		0.5	6.2	4.9	7.4	6.9
3	June 11 1975	0 (only water)	687.9	828.1	586.6	668.8
		0.125	-	-	-	-
		0.25	72.2	177.4	230.4	370.3
		0.5	25.3	25.5	33.1	51.7
	June 24 1975	0 (only water)	783.7	800.0	1188.8	1158.7
		0.125	-	-	-	-
		0.25	49.8	54.9	63.6	102.0
		0.5	23.8	33.3	25.8	39.7
5	June 11 1975	0 (only water)	667.1	579.6	546.7	779.0
		0.125	154.8	149.2	477.6	467.8
		0.25	32.9	62.8	75.4	137.1
		0.5	20.6	18.5	20.7	34.2
	June 24 1975	0 (only water)	109.3	525.8	583.5	620.5
		0.125	97.0	91.8	115.8	144.9
		0.25	75.3	55.7	75.4	79.1
		0.5	38.4	31.9	31.3	33.7
10	June 11 1975	0 (only water)	682.6	562.9	617.3	679.8
		0.125	35.0	77.7	149.6	255.8
		0.25	24.9	23.2	27.1	52.4
		0.5	8.9	9.5	13.3	12.1
	June 24 1975	0 (only water)	485.8	517.2	501.5	679.1
		0.125	82.7	187.0	171.9	407.8
		0.25	51.6	42.6	55.2	68.4
		0.5	21.1	24.5	22.7	27.3

TABLE 6.4 CONDITIONING OF LIME-STABILIZED SEPTAGE (Paulsrud, 1975).

Total suspended solids %	Lime dosage (g $Ca(OH)_2$/ kg TSS)	Dosage of Praestol 444K (% of TSS)	CST with 10 mm reservoir (s)		
			Stirring time after mixing (s)		
			10	40	100
5.2	0	0.25	10.8	16.0	23.1
		0.5	18.0	9.1	11.7
		1.0	40.5	21.4	12.2
5.4	50	0.25	13.2	15.1	-
		0.5	9.6	9.8	-
		1.0	34.0	16.1	-
5.7	100	0.25	29.0	63.6	-
		0.5	13.3	19.0	-
		1.0	10.0	11.4	-
6.3	200	0.25	19.0	35.6	-
		0.5	11.9	14.7	-
		1.0	8.2	11.9	-

TABLE 6.5 CONDITIONING OF LIME-STABILIZED SEPTAGE (Eikum, 1976).

Sampling date 1975	Total suspended solids %	Dosage of Praestol 444K % of TSS	CST with 10 mm reservoir (s)			
			Stirring time after mixing (s)			
			0	10	40	100
Aug. 20	6.0	0 (only water)	94.8	81.4	88.0	78.7
		0.125	9.4	9.2	12.4	14.5
		0.25	7.1	8.2	9.5	10.1
		0.5	6.2	7.1	8.6	8.3
Aug. 28	5.0	0 (only water)	56.9	48.1	51.5	47.2
		0.125	9.4	9.5	10.7	11.7
		0.25	7.7	7.3	9.7	9.4
		0.5	8.8	5.5	8.7	8.1
Sept. 2	6.0	0 (only water)	39.3	44.7	44.1	42.3
		0.125	8.2	10.2	10.5	12.9
		0.25	6.8	6.3	9.3	9.3
		0.5	6.7	5.6	7.2	8.9
Sept. 9	4.5	0 (only water)	219.8	251.3	248.7	240.4
		0.125	12.2	16.1	20.9	30.6
		0.25	6.9	8.3	10.1	11.4
		0.5	5.3	5.8	7.5	6.0
Sept. 30	5.0	0 (only water)	112.0	108.7	105.5	106.0
		0.125	12.3	14.3	20.0	22.2
		0.25	8.4	11.8	13.1	14.6
		0.5	8.2	8.7	8.2	9.4
Oct. 7	-	0 (only water)	72.9	76.4	79.6	83.5
		0.125	11.9	13.4	18.4	21.2
		0.25	-	12.5	13.5	16.2
		0.5	6.9	7.0	10.2	11.0

and storage time are given in Table 6.6, and Figure 6.2 shows the corresponding specific resistance to filtration results. With the highest lime dosage the specific resistance has been decreased to about $4 \cdot 10^{12}$ m/kg, but according to Gale (1971) this would not be sufficient for practical dewatering with vacuum filters and filterpresses.

DEWATERING OF SEPTAGE

When receiving and handling septage at wastewater treatment plants in Norway, the septage is usually mixed with wastewater treatment plant sludges prior to mechanical dewatering. Therefore, there is relatively little practical experience with separate full-scale dewatering of septage. Most of the treatment plants handling septage use centrifuges for sludge dewatering, but various belt filters and filter presses are also in operation. Polymer conditioning is essential for centrifuges, sieves, and belt presses to obtain satisfactory quality of the centrate, while filter presses normally use lime and ferric iron for conditioning.

Centrifuges

The centrifuges used in Norway for dewatering septage and wastewater sludges are all of the solid bowl or decanter type (see Figure 6.3).

Some data from Valle septage dewatering plant (Eikum, 1976) indicate that cake solids concentration of 25 percent and solids capture of 90-95 percent are quite normal with separate centrifuging of screened and degritted septage. Polymer requirements were on the order of 2-4 g/kg TSS.

Centrifuging of lime-stabilized septage at Rambekk wastewater treatment plant showed high solids concentration in sludge cake (25-33 percent TS), but the quality of centrate was not acceptable to be recirculated to the inlet of the primary-chemical treatment plant (see Table 6.7). It is typical for centrifuges that the quality of centrate normally deteriorates with increasing cake solids content.

Several years of experience from many treatment plants with centrifuging of mixed septage/primary-chemical (alum) sludge has demonstrated the following results under normal operating conditions:

Total solids in sludge cake:	20-25 percent
Suspended solids in centrate:	<2000 mg/l
Polymer requirements:	2-4 g/kg TSS.

When adding waste activated sludge to the mixture mentioned above, the cake solids content will normally be reduced to 15-20 percent TS, and the polymer consumption will be raised to the range of 4-6 g/kg TSS to maintain similar centrate suspended solids concentration. It is also a common experience that increasing portions of septage in the wastewater sludge mixtures make it easier to get a higher solids content in the sludge cake without increasing the suspended solids concentration in the centrate. However, the additional septage will cause an increase in sludge water BOD, and this extra organic loading must be considered when recirculating the centrate to the plant inlet.

TABLE 6.6 CHANGE IN pH DURING STORAGE OF LIMED SEPTAGE

Lime dosage (g $Ca(OH)_2$/kg TSS)	pH						
	Days of storage after lime addition						
	0	1	4	7	14	21	28
0	5.7	5.6	5.6	5.5	5.4	5.3	5.3
50	11.1	9.6	8.6	7.7	6.4	5.9	5.8
100	12.3	12.4	12.3	12.2	12.0	11.6	11.4
200	12.4	12.5	12.5	12.5	12.4	12.2	12.4

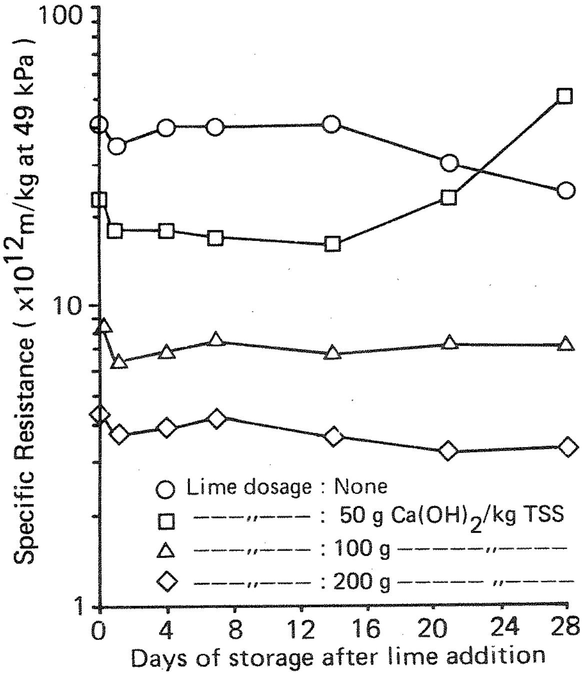

Figure 6.2 Change of specific resistance with lime dosage and storage time.

TABLE 6.7 SUMMARY OF SLUDGE WATER QUALITY. UNTREATED, LIME STABILIZED AND AEROBICALLY STABILIZED SEPTAGE. (Eikum, 1976; Paulsrud, 1975; Sigvaldsen, 1974; Harr, 1976.)

Parameter		Quality of centrate from:					
		Untreated septage		Lime stabilized septage		Aerobic stabilized septage	
		Laboratory centrifuge	Full scale centrifuge	Laboratory centrifuge	Full scale centrifuge	Laboratory thickening	Full scale thickening
TSS	Range	70-2155	723-11790	194-1424	8150-14520	41 - 102	30 - 434
(mg/l)	Median	645	1710	380	11430	59	146
VSS	Range	45-1943	597-10430	119- 896	4920- 9945	19 - 54	16 - 231
(mg/l)	Median	475	1270	214	6870	29	69
BOD_7	Range	206-3195	515- 2865	-	-	5 - 37	9 - 36
(mg O_2/l)	Median	1120	886	-	-	10	15
COD_{total}	Range	378-7998	1285- 9480	3050-8700	9776-28810	79 - 282	140 - 632
(mg O_2/l)	Median	3373	3605	4670	19200	202	181
$COD_{soluble}$	Range	280-5277	563- 1525	2854-5228	2117- 4586	100 - 246	80 - 212
(mg O_2/l)	Median	2791	846	4220	3411	183	159
Total-P	Range	11 - 107	15 - 56	3.4 - 20	39.5 - 116	1.1 - 6.0	0.9 - 4.7
(mg P/l)	Median	47	33	5.7	54	2.7	1.5
PO_4-P	Range	0.4 - 83	0.2 - 49	0.1 - 1.9	0.1 - 3.1	0.4 - 2.5	0.2 - 1.3
(mg P/l)	Median	30	16	0.3	0.2	1.1	0.2
Total-N	Range	37 -529	140 -228	221 - 368	323 - 770	10.8 -42.4	12.4 -34.0
(mg N/l)	Median	199	180	288	553	20	24
NH_4-N	Range	35 -288	65 -128	128 - 203	100 - 160	0.3 - 8	0.2 - 6.4
(mg N/l)	Median	147	80	150	120	0.4	0.5
pH	Range	5.5 - 7.8	-	9.8 -12.5	9.7 -12.4	7.8 - 8.1	7.6 - 7.7
	Median	6.3	-	12.3	12.4	7.9	7.6
Number of samples		23	6	9	6	7	6

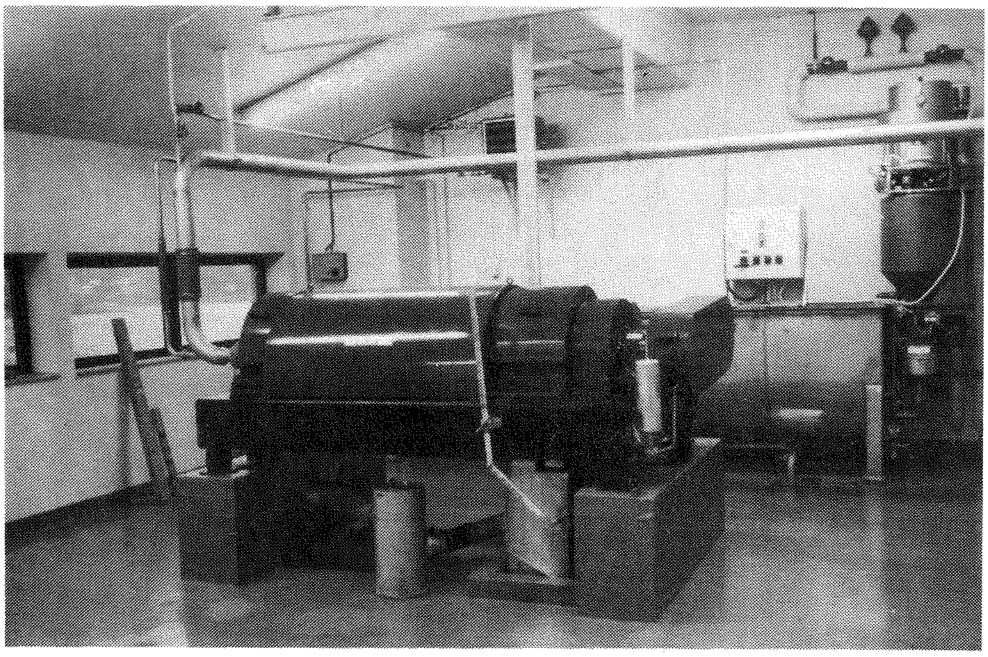

Figure 6.3 Solid bowl centrifuge at Lillehammer Treatment Plant, Norway.

Belt Filters

There are no data from separate dewatering of septage with belt filters in normal operation. Some test results (Ekeberg & Granne, 1972) indicate, however, the same cake solids content as with centrifuges, while the filtrate will contain less suspended solids, partly due to dilution with the filter washing water.

When dealing with septage in combination with wastewater sludge, belt filters in normal operation have shown the same results as stated for centrifuges. Typical filter installations are shown in Figure 6.4 amd 6.5.

QUALITY OF FILTRATE/CENTRATE

All liquid/solid separation processes produce a filtrate/centrate that has to be treated. The quality of the filtrate/centrate will therefore be of vital interest, especially when it is to be treated by biological or chemical processes, either separately or mixed with municipal wastewater.

In a study on untreated septage characterization (Løken, 1973) the BOD_7, COD, orthophosphate, and ammonia content in centrate from laboratory centrifugation were measured. The results are presented in frequency plots (see Figures 6.6, 6.7, 6.8, and 6.9).

When using these data, it is important to note that the suspended solids concentration usually is higher in centrate from full-scale separation processes than in the centrate from laboratory centrifugation. This means that both the BOD and COD values normally will be higher than given in Figures 6.6 amd 6.7.

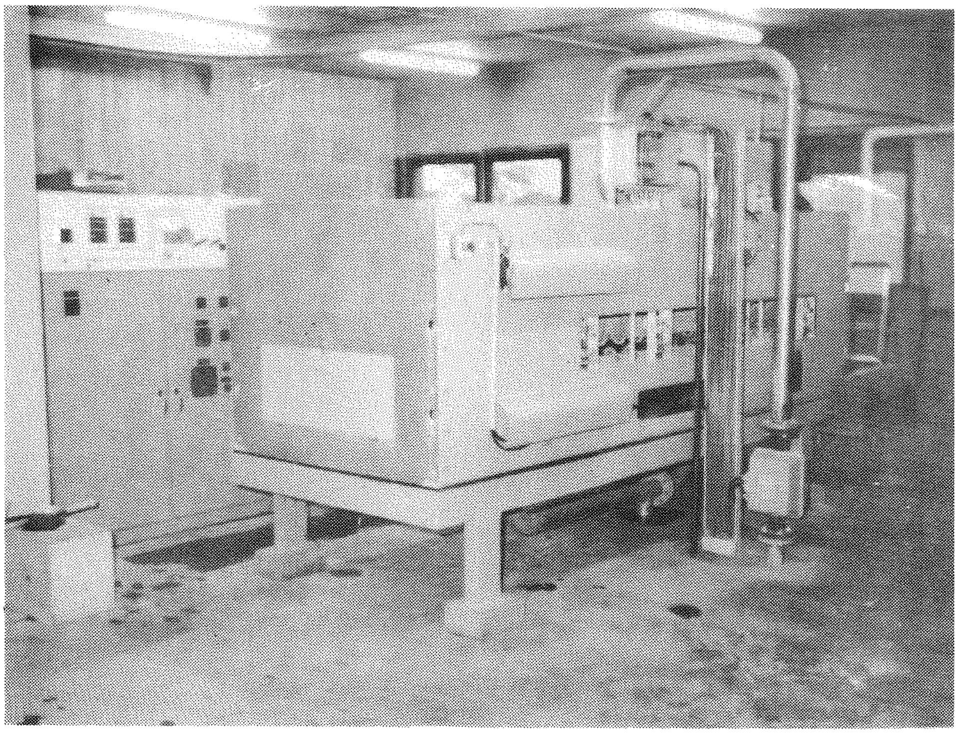

Figure 6.4. Sieve belt press at Rambekk Treatment Plant, Norway.

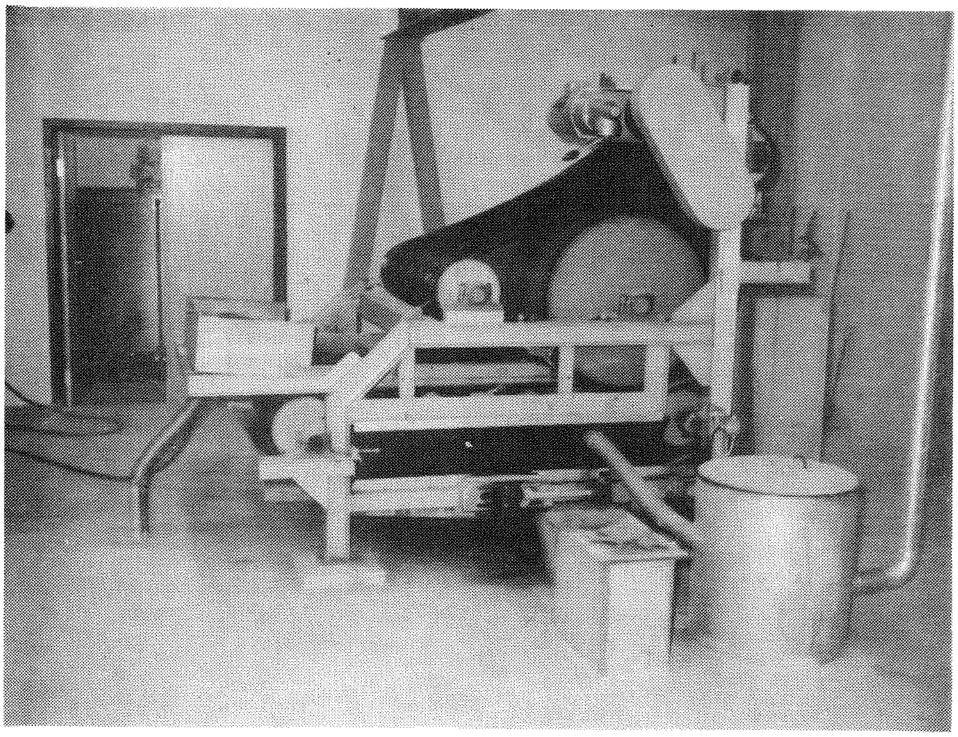

Figure 6.5. Belt press at Brumunddal Treatment Plant, Norway.

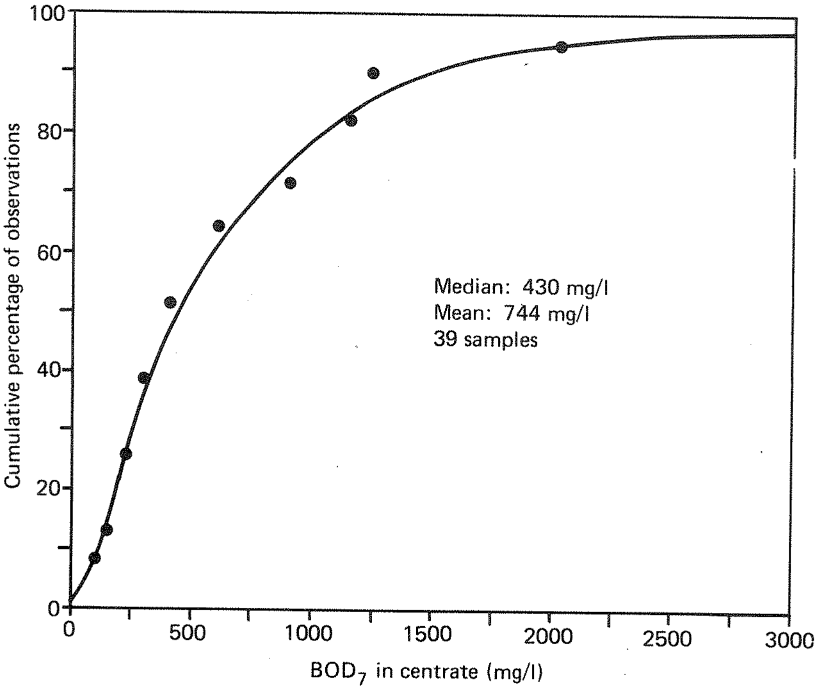

Figure 6.6 BOD$_7$ in centrate from lab centrifugation of untreated sludge.

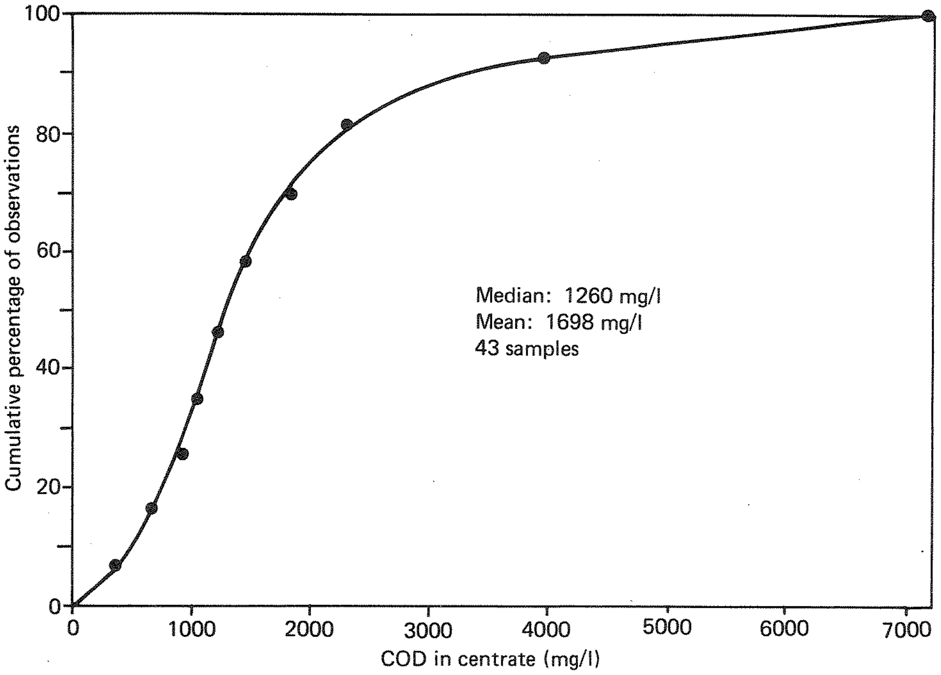

Figure 6.7 COD in centrate from lab centrifugation of untreated sludge.

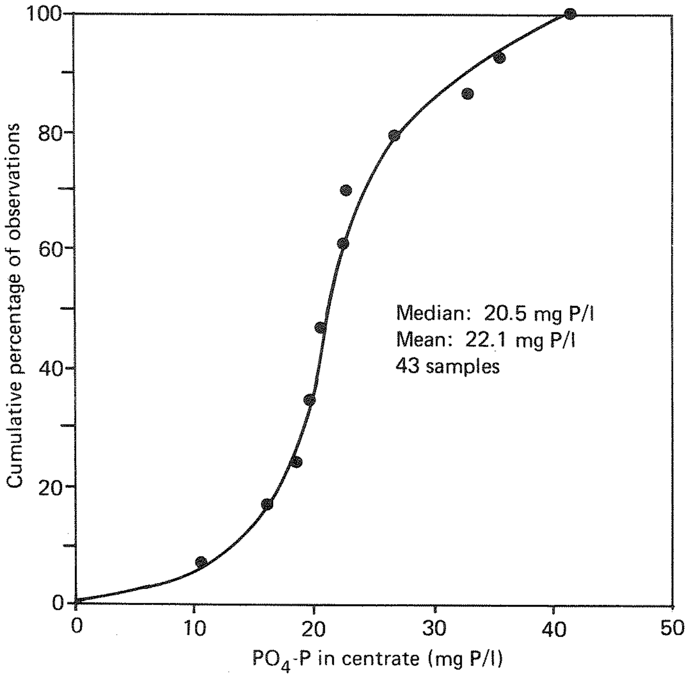

Figure 6.8 Ortho phosphate in centrate from lab centrifugation of untreated septage.

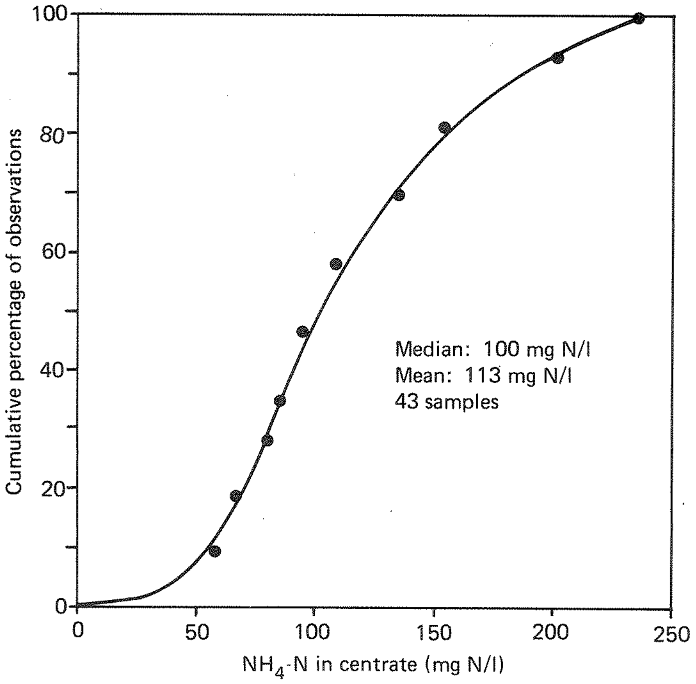

Figure 6.9 Ammonia in centrate from lab centrifugation of untreated septage.

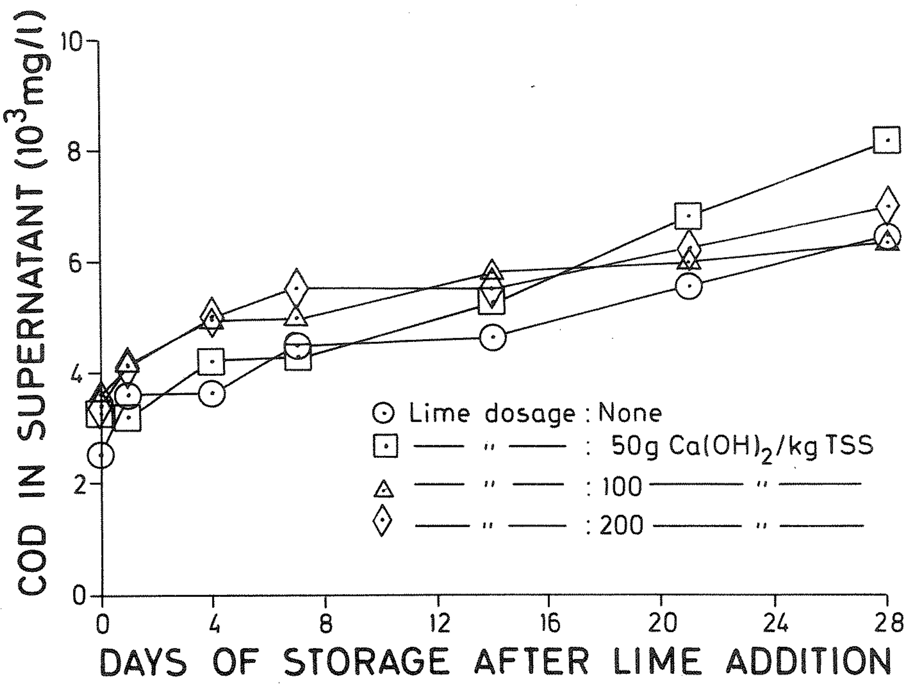

Figure 6.10 COD in centrate from lab centrifugation of lime-stabilized septage.

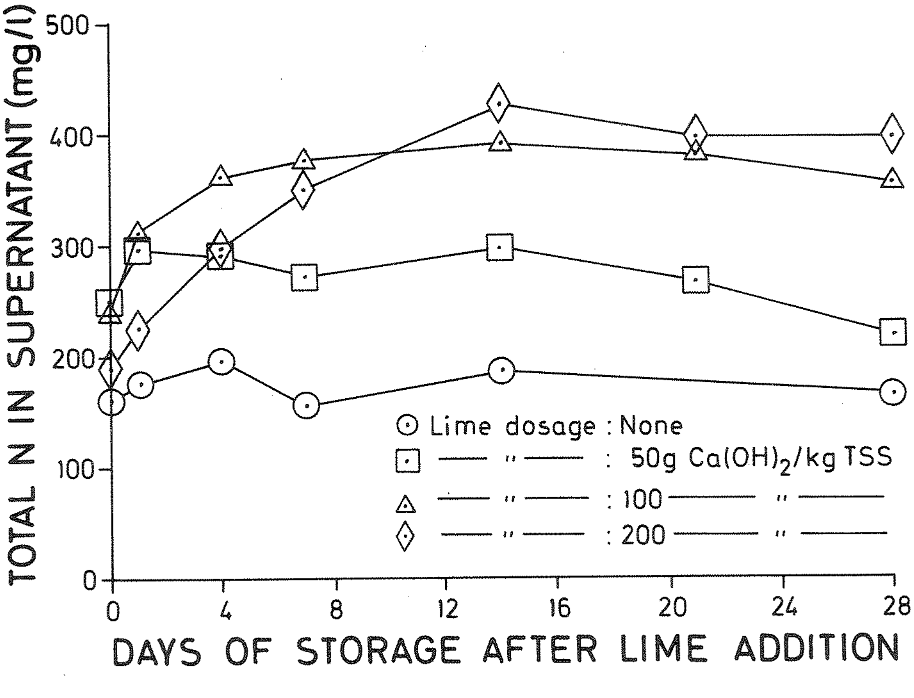

Figure 6.11 Total nitrogen in centrate from lab centrifugation of lime-stabilized septage.

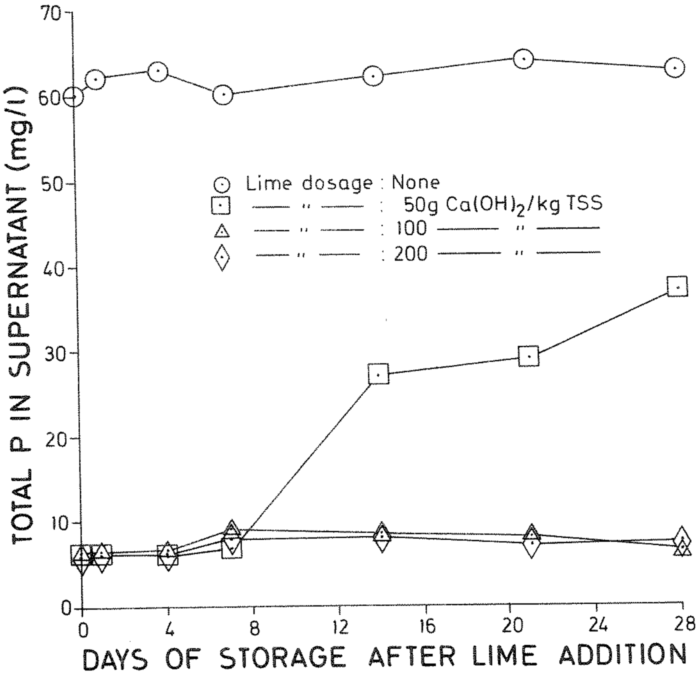

Figure 6.12 Total phosphorus in centrate from lab centrifugation of lime-stabilized septage.

The effect of lime dosage and storage time on filtrate/centrate quality has been studied by Paulsrud (1975). Septage with various lime additions was stored at 20 °C in open containers for 28 days and sampled at a certain frequency during that time. Parts of the samples were centrifuged in the laboratory and the sludge waters were analyzed for COD, total nitrogen, and total phosphorus. Figures 6.10, 6.11, and 6.12 give the results, and the corresponding pH values are presented in Table 6.6.

The increase in COD concentration with increasing storage time is probably caused by anaerobic decomposition of particulate organic matter (the samples with low or decreasing pH) or alkaline hydrolysis (the two samples with no pH drop during the storage period). The same explanation can be used for the total nitrogen curves in Figure 6.11. The precipitation of phosphorus due to lime addition is clearly demonstrated in Figure 6.12. The lowest lime dosage was not sufficient to keep a high pH during the whole storage period and thus the precipitates began to dissolve again.

Data from different studies of sludge water quality have been summarized in Table 6.7. The major conclusion that can be drawn from this material is that lime stabilization of septage will increase the concentration of organic matter and nitrogen in the sludge water while aerobic stabilization will dramatically reduce the same parameters, when compared with untreated septage. However, it should be mentioned that the values given from full-scale centrifuging of lime stabilized septage are higher than normal due to unsatisfactory operation of the centrifuge.

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SECTION 7

EFFECTS OF RETURN FLOWS ON CHEMICAL TREATMENT OF WASTEWATER

GENERAL

The addition of return flows (supernatants, thickener overflow, centrates, filtrates, etc.) to wastewater treatment processes causes increases in loading that reduce effluent quality and cause operating problems. Septage, which is concentrated and collected in batches, is a frequent cause of operational problems in small treatment plants. The problems are especially severe in Norway, where septage accounts for 40 percent by weight of the wastewater solids produced and where 70 percent of the plants serve less than 2000 persons.

In order to reduce wastewater process loadings, septage is commonly received at the sludge handling stream of municipal treatment plants in Norway. It is commonly screened and degritted, then combined with wastewater sludges for thickening and dewatering. Return flow from thickening and dewatering is combined with wastewater at the plant headworks.

Wastewater treatment is often by chemical precipitation, coagulation and settling; sludges are dewatered by centrifuges or presses. Sludge is usually conditioned with polymers to improve dewatering. Lime is sometimes added to reduce odors, notably for septage. In other plants, aerobic stabilization or lime stabilization (high lime dosage) is used prior to dewatering. A typical flow diagram of the major unit processes shows both liquid and solids processing (Figure 7.1). Such a sequence is used at many treatment plants in Norway. The treatment objective is primarily phosphorus and suspended solids removal. However, effluent quality is often good regarding BOD and COD removal as well (Table 7.1).

Process upsets from thickener overflows, and dewatering filtrates and centrates often occur when plants handle a large fraction of septage. The characteristics of these return flows are quite variable, depending both on the particular batches of septage, on the type of septage treatment, and on the dewatering process. The volume is also variable with season, day of the week and time of the day. The majority of the time no treatment of septage is practiced. Occasionally lime (pH > 12) or aerobic digestion is used both to stabilize the septage and to reduce odors around the plant.

Typical concentrations of return flows from dewatering septage are given in Section 6. The liquid fraction from raw septage is similar to that from anaerobic digestion; it is very concentrated in suspended solids (SS), chemical oxygen demand (COD), ammonia, phosphorus, and alkalinity. The return of this liquid fraction to the chemical treatment process results in slightly increased hydraulic loads. However, it greatly increases suspended solids and

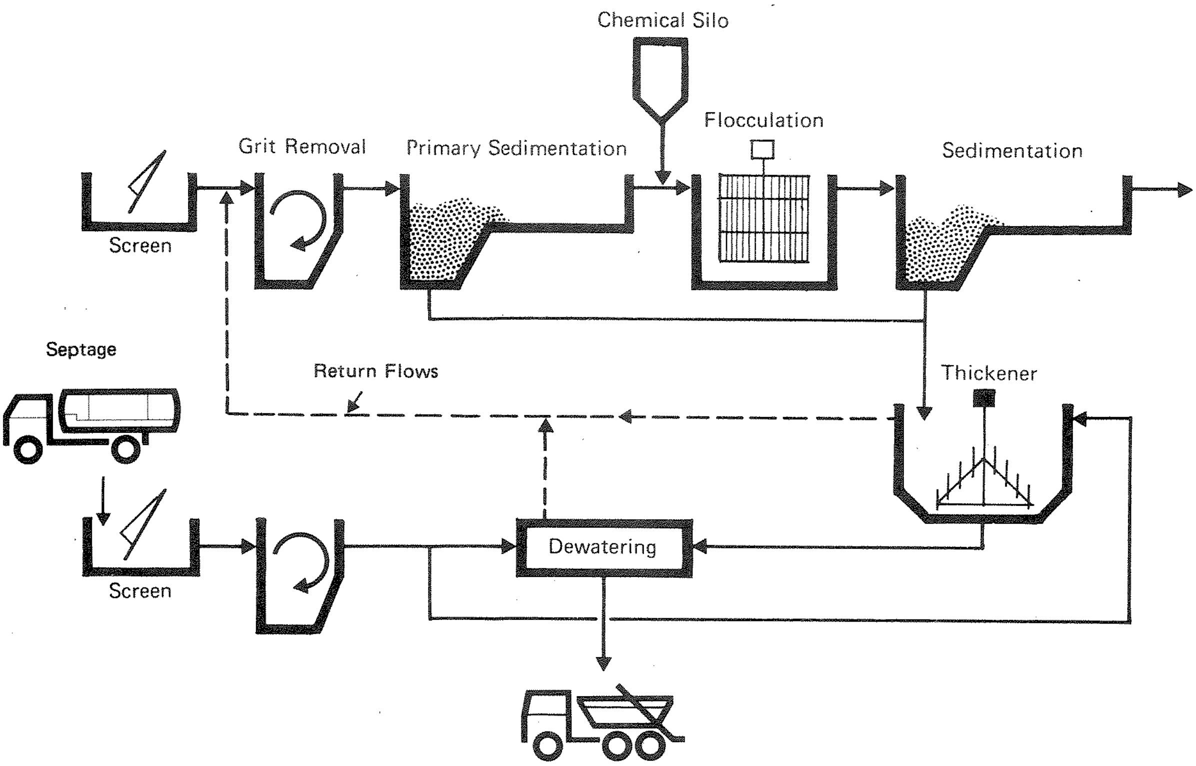


Figure 7.1 Septage handling at a typical primary-chemical wastewater treatment plant.

TABLE 7.1. TYPICAL EFFLUENT CHARACTERISTICS FOR PRIMARY-CHEMICAL MUNICIPAL WASTEWATER TREATMENT PLANT

Parameters		Concentration	% Removal
SS	mg/l	20	90
BOD_7	mg/l	60	70
COD	mg/l	120	70
Total phosphorus	mg P/l	0.6	90
Orthophosphate	mg P/l	0.2	95
pH		6	-
Secchi depth	m	1.5	-
Turbidity	FTU	15	90

organic matter which are difficult to coagulate. Also there are increases in phosphorus and alkalinity, which are the wastewater parameters most directly linked to chemical dosage needed to obtain low effluent phosphate and turbidity. Upsets at treatment plants include reduced removal of suspended solids, BOD and phosphate, often in spite of large increases in alum or iron dosages.

EFFECTS OF RETURN FLOWS OF UNTREATED SEPTAGE ON ALUM TREATMENT OF WASTEWATER

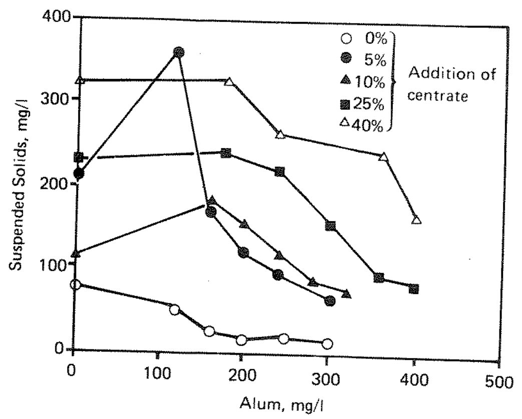
Tests were conducted in 1975 to evaluate the effect of septage liquor on waste treatment with alum (Harr, 1976). The tests involved mixing 5 to 40 percent septage centrate with settled wastewater and then conducting jar tests with varying alum dosages. The results of one such test are shown in Figure 7.2. The residual suspended solids, total phosphate and ortho phosphate are all increased by factors of 10x to 100x compared to the low levels reached with 200 to 300 mg/l alum for the wastewater without septage liquor.

Since acceptable effluent quality is in the range of 0.5-1.0 mg/l total phosphate and 20-30 mg/l total suspended solids, it can be seen that all fractions of septage produce unacceptable effects at all alum dosages tested. The increases are proportional to the fraction of septage. This observation can be made when results at a particular alum dosage (300 mg/l) are replotted versus the fraction of centrate (Figure 7.3). All three parameters increase in proportion to the centrate fractions.

The suspended solids increase is a result of inadequate coagulation of the centrate solids even at alum dosages of 300 to 400 mg/l, which produced much floc at a suitable pH (< 6.3). Extrapolation of the nearly straight line relation between SS and the centrate fraction indicates that 600 mg/l of non-removable, colloidal suspended solids are present in the centrate. They are only diluted in the jar tests. In all tests, the unremovable centrate solids range from 200 to 600 mg/l, representing 8 to 12 percent of the centrate SS, a percentage not very different from that found with other wastewater SS. The contribution to effluent SS, however, is excessive.

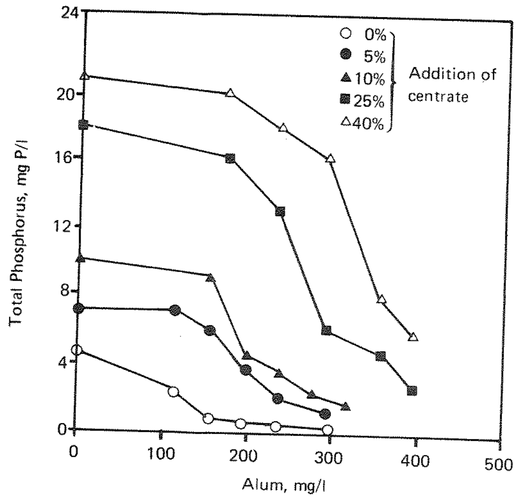
The increase in ortho phosphate that is also seen in Figure 7.3, results from inadequate precipitation of aluminum phosphate. Two mechanisms may be responsible for the high residuals. First, the removal of phosphate requires at least a stoichiometric dosage of alum. Since the septage has much higher concentration of total and ortho phosphate at high fractions of septage and low alum dosages, there simply may not be enough aluminum to precipitate the phosphate. Second, the pH after alum addition may be outside the range for effective precipitation. The higher alkalinity of the septage implies that more alum will be needed to reduce the pH to the optimum for phosphate removal.

In the jar tests under discussion, pH values (for 300 mg/l alum) were between 6.2 and 6.6, - values that permit stoichiometric precipitation. Thus, at high alum dosages the only explanation for high ortho phosphate is insufficient alum for precipitation. At lower alum dosages, alkalinity and pH effects may also have contributed to the high phosphate residuals.



Wastewater Characteristics

	SS mg/l	COD mg/l	Total - P mg P/l	Ortho - P mg - P/l
Centrate	5072	7100	56	49
Primary Treated Wastewater	270	470	7.8	5



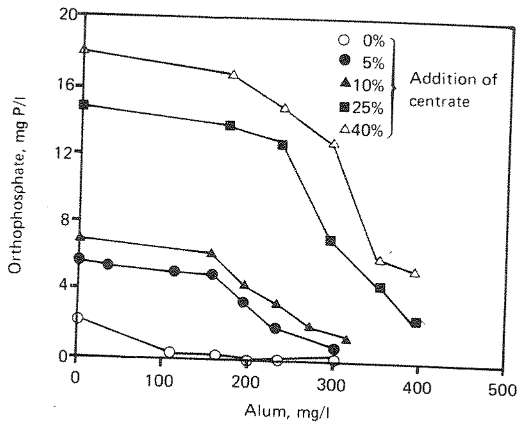


Figure 7.2. Jar test results from alum treatment of septage centrate for varying fractions of centrate in primary treated wastewater (Harr, 1976).

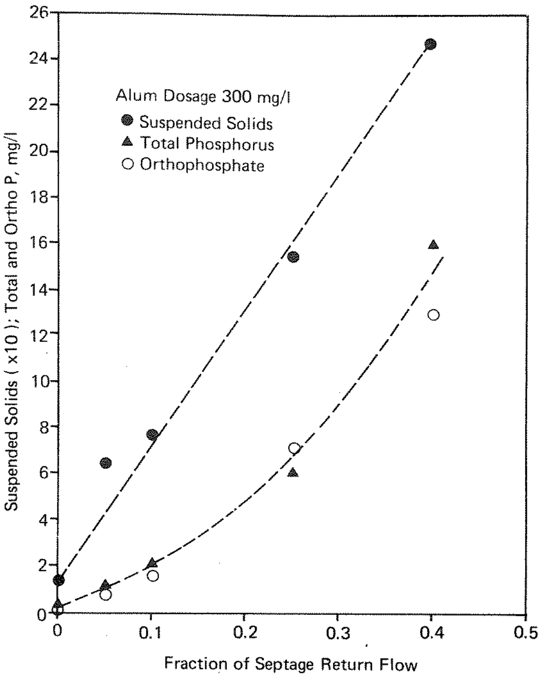


Figure 7.3. Suspended solids, total and ortho phosphate as a function of the septage centrate fraction for an alum dose of 300 mg/l.

The theoretical stoichiometric requirement for precipitation of $AlPO_4$ is 1.0 mole of aluminum per mole of phosphate removed. However, many studies with wastewater have shown that values between 2 and 3 are most commonly attained. The minimal requirement for phosphate removal is about 1.4 to 1.5 (Ferguson and King, 1977). Excellent initial mixing and proper pH values during precipitation are needed to achieve low values. The data from Figure 7.3 are replotted in Figure 7.4 A to show the change in the ratio of aluminum added to ortho and total phosphate initially present. There is excess aluminum available when the wastewater has no septage added ($Al/P > 4$), and insufficient aluminum when the fraction of septage liquor is 0.4 ($Al/P < 1.5$).

Precipitation of aluminum phosphate, of course, involves only ortho phosphate, so the ratio that indicates effectiveness of aluminum phosphate precipitation is properly based on ortho phosphate removed. In the jar test shown at a 300 mg/l dosage, the molar ratio of aluminum to ortho phosphate removed was never lower than 3.2 (Figure 7.4 B), suggesting poor mixing during chemical addition. Calculation of the ratio for all the jar test results yielded values that were no lower than 3.1.

If such a value is the best that can be attained, then only about 10 mg/l of ortho phosphate can be precipitated with 300 mg/l alum. Most of the residual phosphorus was present simply because to little alum is added.

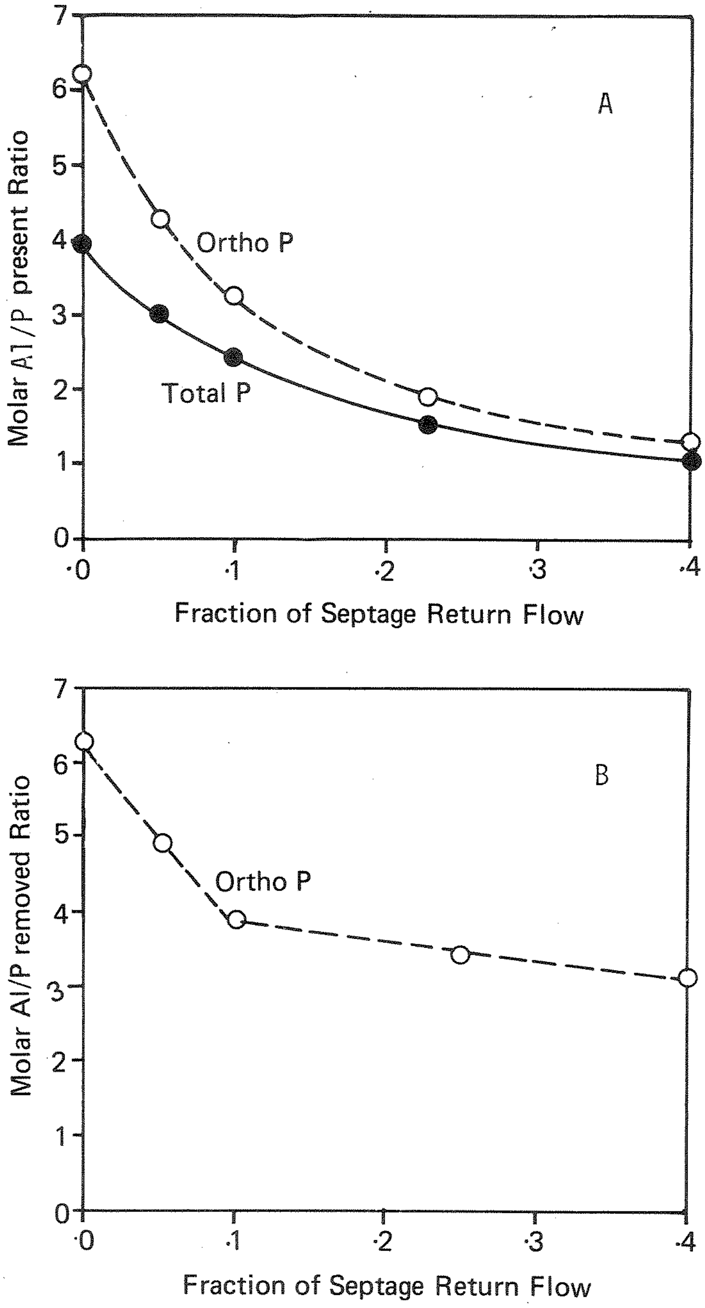


Figure 7.4. Aluminum dosage to phosphate ratios as function of the centrate fractions for alum dosages of 300 mg/l.
A. Ratios based on phosphate values present.
B. Ratios based on ortho phosphate removed by precipitation, coagulation and settling.

This discussion has focused on one jar test series. However, the conclusions are consistent with other dosages and jar tests as well as plant experience. Septage centrate contributes colloidal suspended solids that are not removed by normal chemical coagulation and settling.

Phosphate residuals are also high. While part of the cause may be poor removal of particulate phosphorus or pH values out of the range for optimum coagulation and precipitation, the major factor is inadequate alum addition to precipitate all the ortho phosphate at the rather poor Al/P precipitation ratios attained with centrate.

The implications for handling septage return flows are rather straightforward. Liquor addition will result in some increase in effluent SS which will require better chemical coagulation and particle removal than normally required for wastewater alone. Improved solids capture in septage dewatering is likely to reduce the effect; direct addition of septage to the plant flow is likely to cause even more deterioration in effluent quality since far higher loads of suspended solids are involved.

Coagulation and phosphate removal require pacing of the chemical dose to add sufficient metal ion to precipitate ortho phosphate, destabilize the suspended solids, and to reach the proper pH range. Addition of variable amounts of septage liquor causes large variations in the dosage needed. Present methods of chemical dosing control are inadequate to respond to the variations caused by septage liquor additions greater than a few percent of the plant flow rate. The obvious measure to reduce adverse effects is to flow equalize the septage return flows. In some cases return-flow treatment may also be justified if the amount of septage is greater than a few percent of the average plant flow or if the increase in effluent SS is not acceptable.

EFFECTS OF RETURN FLOW FROM LIME OR AEROBICALLY STABILIZED SEPTAGE ON ALUM TREATMENT OF WASTEWATER

Stabilization of septage, following the research of Eikum and Paulsrud (1975, 1977) for other wastewater sludges, significantly changes the characteristics of the return flow (see Section 6). Lime stabilization requires addition of 100-300 g $Ca(OH)_2$/kg SS to raise the pH above 12 and maintain it above 11 for at least 14 days. Aerobic stabilization implies aeration long enough to produce a reduction in odor intensity and odor increase during storage (see Section 5).

Centrate from dewatering stabilized sludges are combined with wastewater flows and treated with chemicals for phosphate and suspended solids removal in treatment schemes similar to that in Figure 7.1. Jar tests, conducted by Harr (1976), can be summarized briefly. Lime stabilization produces a centrate low in phosphate but with high BOD, alkalinity and pH. Mixture of small fractions results in excessive alkalinity in the wastewater and in excessive alum dosages to reach the correct pH range for coagulation/precipitation. Lime sludge stabilization is truly incompatible with alum or iron salt treatment of wastewater. Even moderate dosages of lime for odor control or sludge conditioning cause drastic increases in alum or iron dosages.

Aerobic stabilization results in a centrate with low suspended solids, BOD, ortho phosphate (Table 6.7) and reduced alkalinity due to nitrification. Alum treatment of wastewater is not significantly impacted by centrate from aerobic stabilization.

ACTIVATED SLUDGE TREATMENT OF SEPTAGE CENTRATE

In instances where stabilization of septage is not necessary, but where effects of return liquors are unacceptable, biological treatment of the liquors may be used. Tests were conducted at NIVA to determine the amenability of septage centrate to activated sludge and rotating biological disc treatment.

Four activated sludge units and one rotating disc unit were used to treat septage centrate in the winter 1979/80. The units were operated for four weeks to reach stability, then data were collected for seven days. The characteristics of the septage feed during the test period are presented in Table 7.2.

TABLE 7.2. SEPTAGE CENTRATE FROM TAU TREATMENT PLANT, TØNSBERG, NORWAY

pH		7.0
Alkalinity	mg/l $CaCO_3$	245 ± 20
Total COD	mg/l	2400 ± 1300
Soluble COD	mg/l	250 ± 30
BOD_7	mg/l	640
Total suspended solids	mg/l	2270 ± 1500
Volatile suspended solids	% of TSS	76
Total phosphate	mg P/l	13
Ortho phosphate	mg P/l	4.6
Total volatile acids	mg/l $CaCO_3$	145
NH_4-Nitrogen	mg N/l	60
Total Kjeldahl Nitrogen	mg N/l	120

The centrate was slightly weak with respect to organics, alkalinity, and especially phosphate, but is not atypical of septage which of course is extremely variable (see Section 6). Temperature in the reactors was 10 ± 2 °C during the test period. The process loadings were based on solids residence time for the activated sludge units and on areal loading for the rotating biological contactor (RBC) discs. The values during the experimental period are presented along with other operating data (Table 7.3). All units had long hydraulic residence times and conservative biological loadings.

TABLE 7.3. OPERATING CHARACTERISTICS OF BIOLOGICAL UNITS

Activated sludge	Unit 1	Unit 2	Unit 3	Unit 4
Reactor volume, liters	16.7	18.3	17.7	17.0
Mixed liquor volatile suspended solids, mg/l	2400±170	5100±820	3000±520	2600±250
Hydraulic residence time, d	7.7	4.1	2.0	1.4
Solids residence time, d	25	16	6.6	4.7
Food to micro-organisms ratio, gr COD/gr MLVSS·d	0.13	0.12	0.41	0.67
Food to micro-organisms, gr BOD_7/gr MLVSS·d	0.035	0.032	0.11	0.18

Rotating Biological Contactor (RBC)	
Number of chambers	4
Disc area per chamber	1.07 m^2
Tank volume per chamber	8 liters
Hydraulic residence time	3.1 days
Area COD loading, 1st chamber	23.4 gr/m^2·d
Area COD loading, overall	5.9 gr/m^2·d

Process performance is summarized in Table 7.4 for organics, solids, phosphate, and nitrogen. The activated sludge units removed between 92 and 96 percent of BOD_7 and suspended solids, while the RBC removed about 75 percent. COD removals were about 80 and 50 percent, respectively.

Performance of the RBC was not adequate for treatment of septage return flow. The RBC chambers accumulated sludge during the test. The bio-film tended to become very thick, then slough and reform only slowly. The dissolved oxygen, though, was above 5 mg/l in the last two chambers. It is believed that the very high fraction of particulate organics was not readily usable by bacteria in the bio-film. The particulates did ferment to some extent in the reaction chamber, so that there was an increase in soluble COD in the RBC effluent.

The activated sludge units produced high organic and suspended solids removals. They nitrified at solids residence times of 6.6 days or longer, and removed alkalinity and ortho phosphate to varying degrees. The relatively long detention times mean that somewhat stronger centrate than given in Table 7.2 fed before the test period, influenced the effluent during the test period. Hence the degree of removal or change cannot be calculated precisely for these parameters.

The effluent characteristics are similar to the values for centrate from aerobic stabilized septage. Either form of aerobic treatment substantially eliminates the adverse effects of return flows on chemical treatment.

The mitigation of effects on chemical treatment was tested by conducting jar tests with 15 percent treated and untreated centrate mixed with a synthetic wastewater. The results of tests show a moderate effect of treatment on pH and ortho phosphate values (Figure 7.5). The pH values were about 0.1 unit lower and the ortho phosphate values about 50 percent lower for the activated sludge treated centrate than for raw centrate. These results are consistent with those described above for raw and aerobically stabilized centrate. The differences are due to reduced alkalinity and ortho phosphate due to activated sludge treatment. The activated sludge treated centrate produced noticeably less turbidity in the jar tests. However, suspended solids and total phosphate were not measured in the tests.

Activated sludge treatment of septage return flow is feasible, preferably at solids retention time of > 7 days and food to micro-organisms ratio of < 0.1 mg BOD_7/mg MLVSS·d. These values will result in a nitrified effluent with low alkalinity and ortho phosphate approximating wastewater values. The process hydraulic detention time is about 4 days and can be operated at a MLVSS of about 3000 mg/l ($\sim$ 4500 mg/l MLSS). Such treatment of septage centrate will mitigate effects on chemical treatment in much the same way as aerobic stabilization of septage.

PRACTICAL EXPERIENCE REGARDING EFFECT OF RETURN FLOWS ON PLANT PERFORMANCE/DISCUSSION

The effects of septage return flow on wastewater treatment plants are dependent upon the quality and quantity of return flow, the flow variations of return flow, and the type and loading of the municipal plant that receives the return flow.

TABLE 7.4. EFFLUENT CHARACTERISTICS AND PERCENT REMOVALS FOR BIOLOGICAL TREATMENT OF SEPTAGE LIQUORS

Parameters	Activated Sludge								RBC	
	No. 1		No. 2		No. 3		No. 4			
	Concen- tration	% Re- moval	Concen- tration	% Re- moval	Concen- tration	% Re- moval	Concen- tration	% Re- moval	Concen- tration	% Re- moval
pH	6.1-6.7		7.0-7.3		7.1-7.4		7.5-7.8		7.4-8.0	
Alkalinity, mg/l $CaCO_3$	20		85		88		185		295	
Total COD, mg/l	410±270	83	590±200	75	460±230	81	410±93	83	1250±510	48
Soluble COD, mg/l	170	32	365	(46)*	185	26	240	4	393	(57)*
BOD_7, mg/l	26	96	36	94	36	94	40	94	136	79
Suspended solids, mg/l	125±75	94	180±110	92	180±120	92	100±30	96	620±290	73
Volatile suspended solids, % of SS	65		63		69		61		67	
Total phosphate, mg P/l	13		4.9		4.5		7		23	
Ortho phosphate, mg P/l	11		3		4.5		6		18	
Total volatile acids, mg/l $CaCO_3$	-		-		-		30		40	
NH_4-Nitrogen, mg N/l	8		6		15		41		60	
NO_2 + NO_3-Nitrogen, mg N/l	58		24		25		<0.5		<0.5	
Sludge volume index, ml/g	62		162		64		73		-	

* ( ) indicate increase.

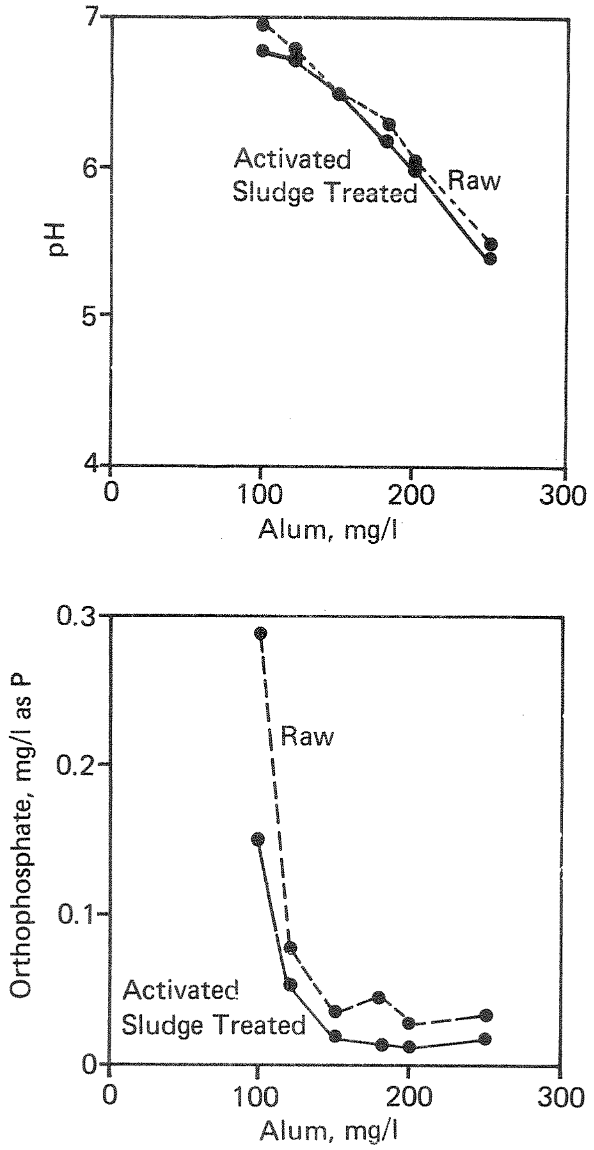


Figure 7.5. Jar test result for 15 percent addition to unit 4 activated sludge treated centrate and raw centrate to a synthetic wastewater.

It has been shown that if the effluent requirements are not stringent, small quantities of septage return flows can be accepted. However, in most countries the effluent requirements are so stringent that even small quantities of thickener overflow or dewatering filtrate will require flow equalization and close process control (especially if chemical treatment is practised).

The information given in this section also points out that if the septage return flow addition rate is high, the optimum chemical addition cannot produce a high quality effluent. Aerobic treatment of the septage before solids separation or separate aerobic treatment of the septage return flow is needed.

From a theoretical point of view the "acceptable" quantity of septage return flows can be calculated.

Septage return flows may contain up to 600 mg/l of suspended solids that are highly resistant to coagulation and settling. These solids increase turbidity and total phosphate in chemically treated effluent. If an addition of 10 mg/l of these solids (∿ 10 turbidity units and 0.2 mg/l phosphorus) to the effluent can be accepted, then an instantaneous addition of septage liquor of 1.7 percent is acceptable. Since septage return flow is commonly produced during the 5 day week, 7 hour/day operation of dewatering, a total volume of septage return flow of about (35/168 x 1.7) or 0.4 percent of the average plant wastewater flow can be accepted without flow equalization. This corresponds to about 0.5 percent septage to wastewater flow over any weekly period. We have then not taken into account any septage return flow from the thickeners.

In practice the fraction of septage return flow that can be treated in primary-chemical treatment plants without causing severe operational problems, is higher than that indicated by the theoretical approach given above. One factor that will influence this, is that effluent quality control is based on composite samples. The short-term effects of septage return flow on effluent quality will therefore be masked.

A study was made at 6 treatment plants, 4 with septage addition and 2 without, to find if plants with septage addition had higher yearly alum consumption than those without. The Gjerdrum Plant (see Table 7.5) used an average of 580 g/m^3 alum in 1978 and 435 g/m^3 in 1979. This is 3-4 times the normal dosage, and the reason is the septage addition. The plants in Table 7.5 all meet the effluent requirements regarding phosphorus removal, but not with respect to BOD. If the BOD must be reduced at a primary-chemical treatment plant, the use of aerobic treatment of centrate is cost-effective compared to aerobic stabilization of all the septage. A detention time of about 4 days can be used instead of 14 to 20 days, and the oxygen required is reduced by the solids capture factor for centrifugation (approximately 95 percent).

Medbø (1975) and Eikum et al. (1978) reported on the experience with septage addition at Løxa Treatment plant in Norway. The flow diagram of the plant is shown in Figure 7.6. The primary and chemical sludges and septage were mixed in the mixing chamber after the plant was first put into operation. Later the septage entered the second thickener while the wastewater sludges were thickened in the first thickener. The overflow from the thickeners and the centrate are recycled to the plant inlet. Table 7.6 shows the treatment result with respect to BOD$_5$ and total phosphorus (Medbø, 1975).

TABLE 7.5. ALUM CONSUMPTION AT PRIMARY-CHEMICAL TREATMENT PLANTS WITH AND WITHOUT SEPTAGE ADDITION

Treatment plant	Design capacity	Sludge dewatering	Septage addition	Lime treatment of sludge	Alum used (ton/yr)		Aver. dosage (gr/m^3)	
	persons				1978	1979	1978	1979
Gjerdrum	2,500	X	X	high (pH 10-11)	34	31	580	435
Nannestad	2,500	X	X	low (pH 7-8)	36	45	270	250
Bjørkelangen	2,500	X	X	low (pH 7-8)	33	37	330	225
Jessheim	10,000	X	X	None	150	155	250	235
Harestua	2,500			low (pH 7.2)	6.5	14	140	235
Maura	2,500			low (pH 7.2)	18	24	100	110

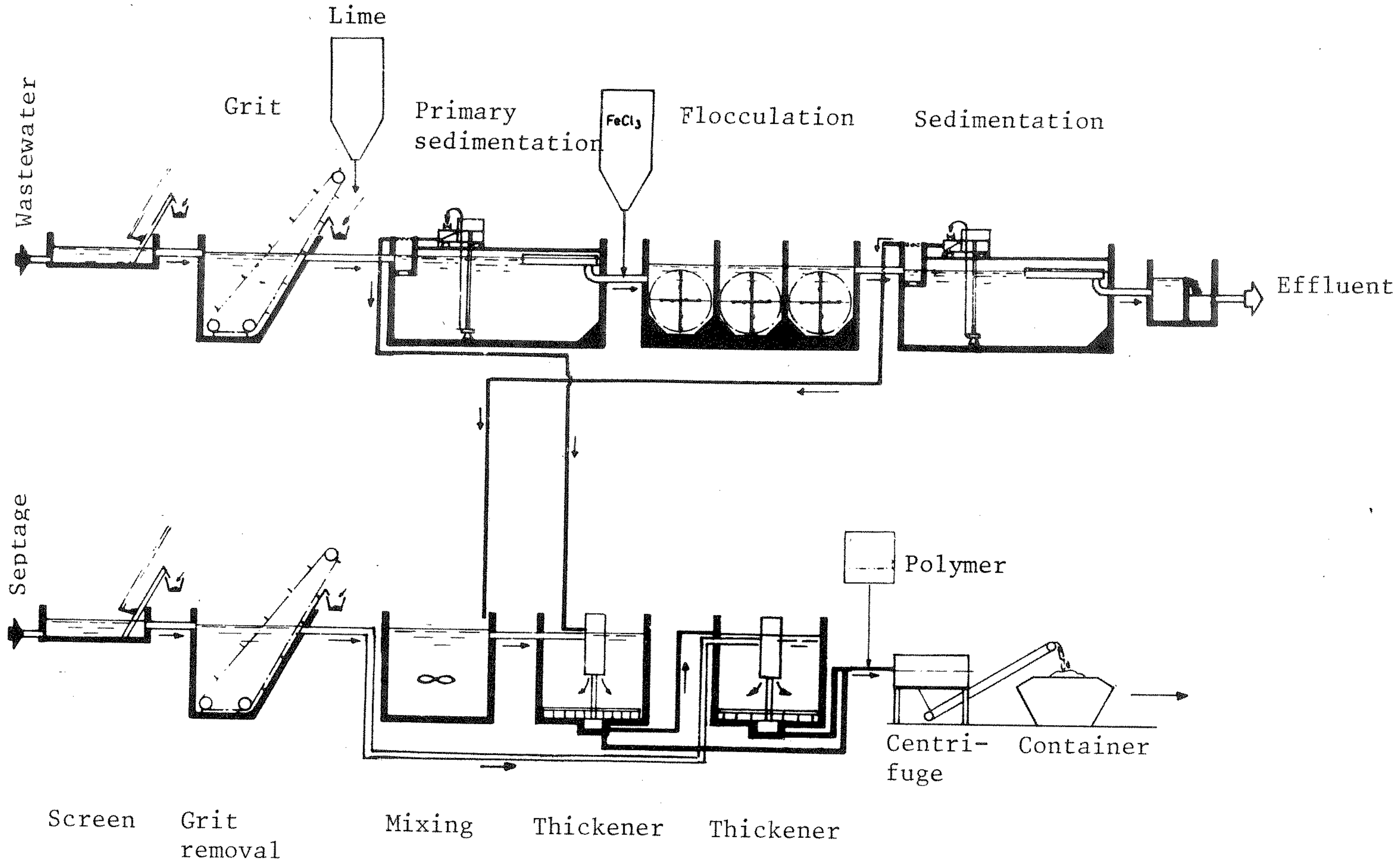


Figure 7.6. Flow diagram of the Løxa Treatment Plant.

TABLE 7.6. TREATMENT RESULT AND RETURN FLOW QUALITY AT LØXA TREATMENT PLANT, NORWAY (Medbø, 1975).

	Without septage		With septage	
	BOD_5 mg/l	Tot-P mg P/l	BOD_5 mg/l	Tot-P mg P/l
Screened wastewater	200	5-6	300-400	9
Effluent	40-60	0.8	80-90	0.8
Centrate from centrifuge	500	3-4	1300-1400	15-20
Overflow trom thickener	200-300	2-3	500-600	6

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SECTION 8

REMOVAL OF ODORS FROM FACILITIES RECEIVING SEPTAGE

INTRODUCTION

Collection and handling of wastewater and sludge have caused odor problems for many years.

Rose wrote in 1931: "Odor problems are frequently one of operation, but recent developments have indicated that much of the difficulty can be anticipated and practically eliminated." (Rose, 1931.)

Today it must be concluded that Rose's statement remains appropriate. Solutions for odor problems exist, but too often the problems are not foreseen. New treatment plants are built close to populated areas, and once isolated plants have been gradually surrounded by new dwellings. Today the public is more aware of odor problems and no longer accepts strong odor emissions from wastewater treatment plants.

Everybody understands that wastewater treatment plants are a necessity. It must also be clear that facilities treating septage will cause odors. The question must therefore be: "How is it possible to minimize the emissions?"

Until 5 years ago, the only odor reduction method used at wastewater treatment plants in Norway besides dilution, was activated carbon filtration of the polluted air. Recently, odor problems have been taken much more seriously. As a result, new odor reduction systems have been installed at different plants.

Often it is difficult to predict in advance the nature of treatment plant odor problems. Some generalizations are, however, possible. Generally, plants treating only wastewater do not cause odor problems to the same extent as plants receiving large quantities of septage. It is possible to predict where in the plants the odor emissions are likely to be strongest, e.g., pretreatment units, holding tanks, reject water from dewatering units, etc. Very often the total odor reduction from a treatment plant would be more successful if exhaust systems at the odor sources were used more frequently. Cleaning the total ventilation air volume can be expensive. Proper use of local exhaust systems directly at the odor sources decreases the amount of air that has to be cleaned and, thus, the cost. At many plants designers have realized this and have provided effective odor removal, even though only a very small part of the total ventilation air is treated.

VARIATIONS IN ODOR INTENSITY AT PLANTS RECEIVING SEPTAGE

Practical experience indicates that the odor intensity varies considerably during the day at plants receiving septage. The reason for this is that each truckload of septage can vary with respect to the amount of odorous gases it gives off when the sludge is emptied at the plant. At TAU Treatment Plant in Norway investigations were made regarding H_2S and NH_3 concentrations during the day (Eikum, 1976). Composite samples each hour were taken from the room containing the screen and the grit chamber. Results from a typical winter and summer day are shown in Figures 8.1 and 8.2.

The ammonia concentration in the air at the receiving facility did not fluctuate to the same extent as the hydrogen sulfide. The reason for this is probably that the ammonia is stripped off gradually in the grit chamber rather than escaping into the air when the septage is pumped into the receiving channel in front of the screen. This has not been proven through experiments.

HOW TO MEASURE ODORS

When working with odor problems and odor reduction, two factors are important:

1) The total odor strength
2) Which organic components contribute to the total odor.

Total Odor Strength

Total odor strength in most instances was measured by use of an olfactometer (see Figure 8.3).

The olfactometer supplies 6 dilution levels. At each dilution level, 3 samples ("triangle") are presented to the panelist (the total panel consists of 7-9 panelists) from a set of glass sniffing ports: two are test room air (blanks), and the third is the odorous gas diluted with the test room air. The panelist is instructed that one of the three ports in each set may exhibit an odor, and that his task is to smell the effluents from the ports and find which port, in his opinion, delivers an odorous sample. He must decide; if he feels that none of the three ports delivers and odor, he must simply make a guess.

The panelist proceeds from the most diluted sample towards higher concentrations of the sample. The choice is signalled by depressing a button corresponding to the port thought to be odorous, and this choice is observed by the panel leader on a panel of lights in a separate signal box.

The panel leader records the judgements and calculates data following a statistical procedure which results in an averaged panel value termed ED_{50}. This term denotes Effective Dosage at the 50 percent level; it is that dilution at which 50 percent of the panel would, and 50 percent would not detect odor of the diluted sample. The dilution is denoted by the dilution factor. For instance, $ED_{50} = 1000$ means that one liter of the odorous air must be diluted with 1000 liters of non-odorous air to reach the panel threshold termed ED_{50}.

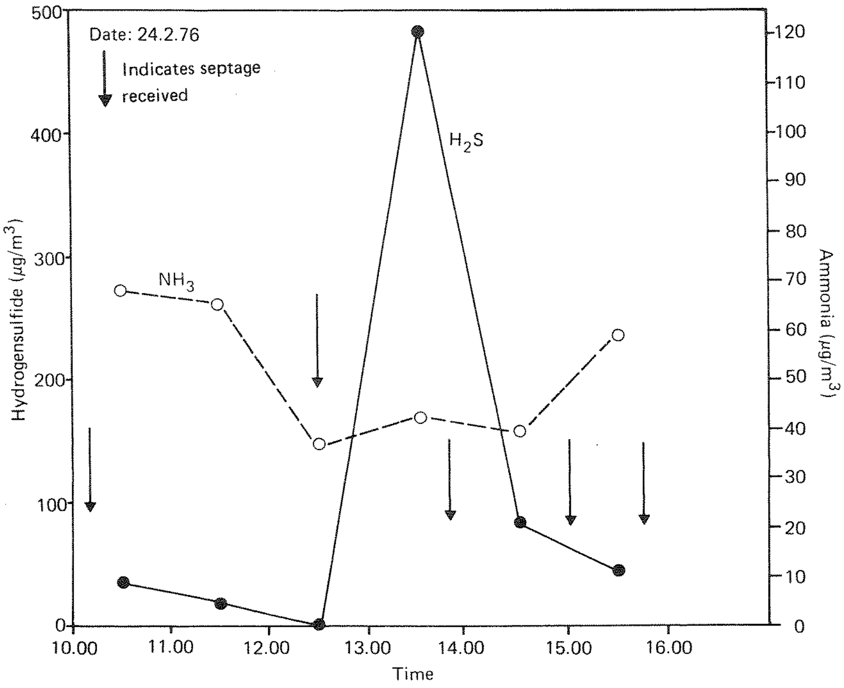

Figure 8.1 Variations in NH_3 and H_2S concentrations at TAU Treatment Plant when receiving a septage, Feb. 24, 1976 (Eikum, 1976).

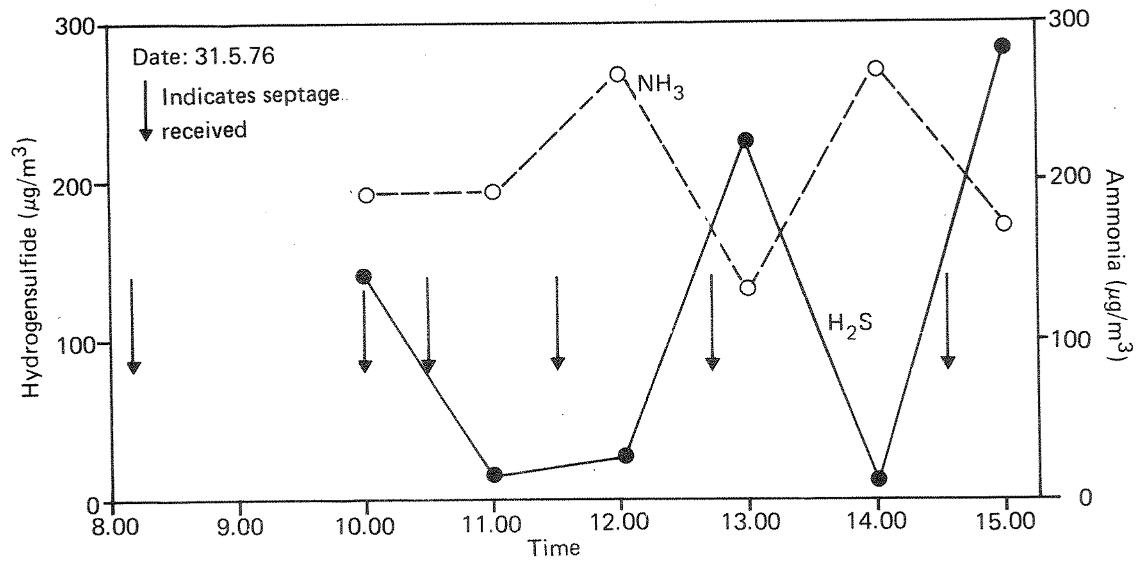

Figure 8.2 Variations in NH_3 and H_2S concentrations at TAU Treatment Plant when receiving septage, May 31, 1976 (Eikum, 1976).

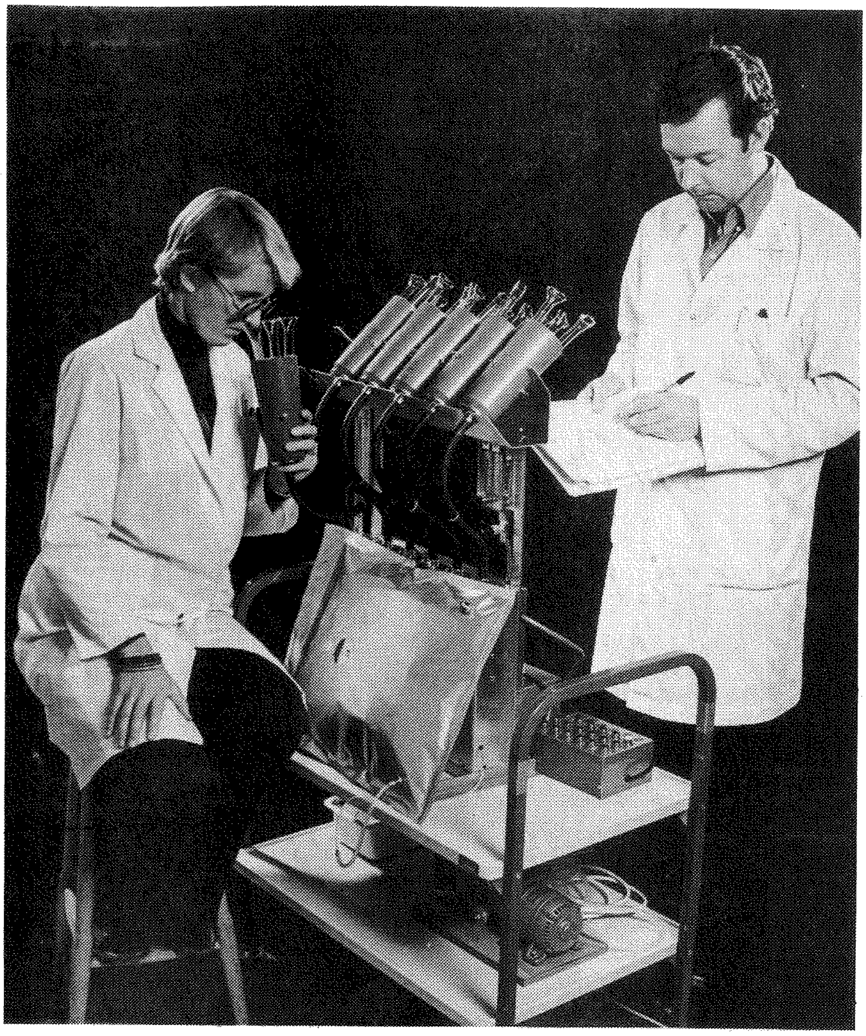

Figure 8.3. Olfactometer in use.

With the olfactometer in use, it is possible to measure dilutions between 10 and 30,000.

Experience has shown that the ED_{50}-value measured in the laboratory can be transferred to the actual odor emission. This can be done because the measurement takes place in a room completely free from foreign odors, and specially tested, motivated panelists are used.

Air samples are collected in special plastic bags. After collection, the bags can be stored for some time. Experiments with wastewater odors have indicated that up to 48 hours storage does not influence the sample.

Odor Threshold and Analysis of Odorous Components

Different chemical components have different odor threshold values. These threshold values can be measured in different ways, and are reported in the literature (ASTM, 1978).

The relationship between odor intensity and the concentration of different organic compounds, can be expressed as follows:

$$I = KC^n; \log I = \log K + n\log C$$

where

I = odor intensity
C = concentration of the odor reaching the panelist's nose
K,n = coefficients, n is normally between 0.2 and 0.8.

By varying the coefficient n, it can be seen that two samples with the same concentrations would give different intensities. Also the equation tells how difficult it can be to reach minimum odor intensity. The reduction of the concentration has to be high. If $n = 0.25$ and the concentration decreases to 1/16 of its original value, the intensity will only decrease to half of its original value. This means that even if the odor components are reduced about 90 percent, very little has actually happened to the odor intensity.

Besides the odor threshold limit values, it is helpful to look at the threshold limit values for specific chemical substances in the laboratory with a controlled environment when discussing odor emissions from sewage treatment plants.

Table 8.1 gives the values for some non-odorous and odorous compounds, and the interesting thing is the difference between the threshold limit values for the most odorous compounds. Hydrogen sulfide with a very low odor threshold would exhibit strong odor although its concentration is far below the threshold limit value. For the non-odorous compounds the opposite happens. The threshold limit values are reached long before one can smell the compounds.

Investigations dealing with total analysis of all organic components present in air from treatment plants, have been carried out (EPA, 1973; Henry et al., 1980; Ando, 1980). Without going into details, one must conclude that the most interesting groups of compounds causing bad odors when treating septage are: sulfides, mercaptans, amines, aldehydes, organic acids, and skatoles.

CHEMICAL SCRUBBERS

At about 15 wastewater plants in Norway, chemical scrubbers have been installed. The scrubbers range from small units (capacity 1500 m^3/h), reducing odor from a dewatering unit, to large scrubbers (ca. 70,000 m^3/h) cleaning part of the total ventilation air from a plant.

All chemical scrubbers utilize hypochlorite as oxidizing agent. The scrubbers are either single- or two/three-stage scrubbers. Generally it can be concluded that the installation and use of the scrubbers have been quite successful.

TABLE 8.1. ODOR THRESHOLD VALUES AND THRESHOLD LIMIT VALUES FOR SOME ORGANIC COMPOUNDS. ALL VALUES GIVEN AS mg compound/m^3 AIR.

	Odor threshold mg/m^3 air	Threshold limit values* mg/m^3 air
Benzene	ca. 15	3
Acetic acid	ca. 3	25
Ethanol	ca. 200	1900
Hydrogen sulfide	ca. 0.01	15
Chlorine	ca. 0.05	1.5
Mercaptans	ca. 0.001	ca. 1
Skatole	ca. 0.0008	-
Buturic acid	ca. 0.05	-

* Norwegian limit values 1981.

Both scrubbers generating NaOCL on site and scrubbers using NaOCL as a liquid are used at plants receiving septage. In Figure 8.4 a two-stage scrubber, type Steuler, is shown. The first stage is an alkaline oxidation (NaOH + NaOCL) and the second stage is an acidic wash using H_2SO_4. Figure 8.5 shows an installation at Bekkelaget Treatment Plant in Oslo, Norway.

One problem that arose soon after installation of this Steuler scrubber, was the addition of acid and base. The scrubber had no automatic dosage system for these chemicals. After an accident occurred, automatic equipment was installed. Automatic control is a necessity when using such concentrated and corrosive chemicals.

The other type of chemical scrubber used at treatment plants that receive septage (Pepcon), generates sodium hypochlorite by electrolysis of salt, NaCl. All Pepcon scrubbers installed in Norway have been single-stage scrubbers, and the oxidation occurs at pH 8-9.

Because the scrubber produces hypochlorite and no acidic step is involved, there is no need for special care concerning handling and dosing of dangerous chemicals.

A Pepcon scrubber is shown in Figure 8.6.

The results from total odor strength measurements of different chemical scrubbers, show odor reduction efficiencies between 95 percent and 98 percent. ED_{50} of the cleaned air has been found to be between 50 and 100, and the air has been characterized as "free from sewage odors, but it smells like chemicals". It seems as if a chemical scrubber always gives this "scrubber odor". If the

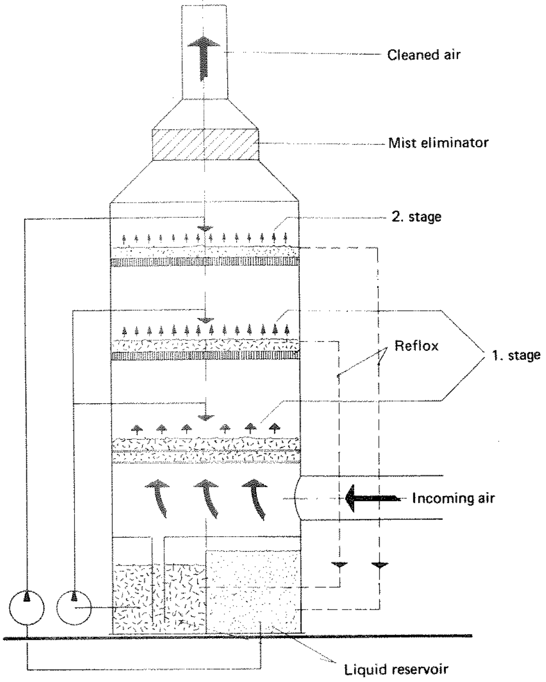

Figure 8.4 Chemical scrubber, type Steuler.

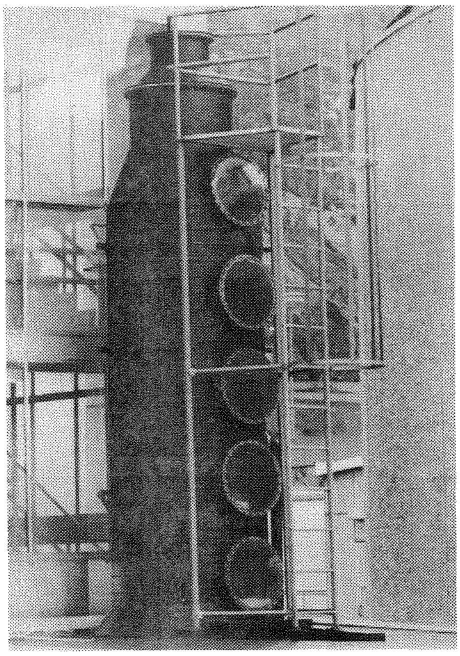

Figure 8.5 Chemical scrubber at Bekkelaget Treatment Plant in Oslo, Norway.

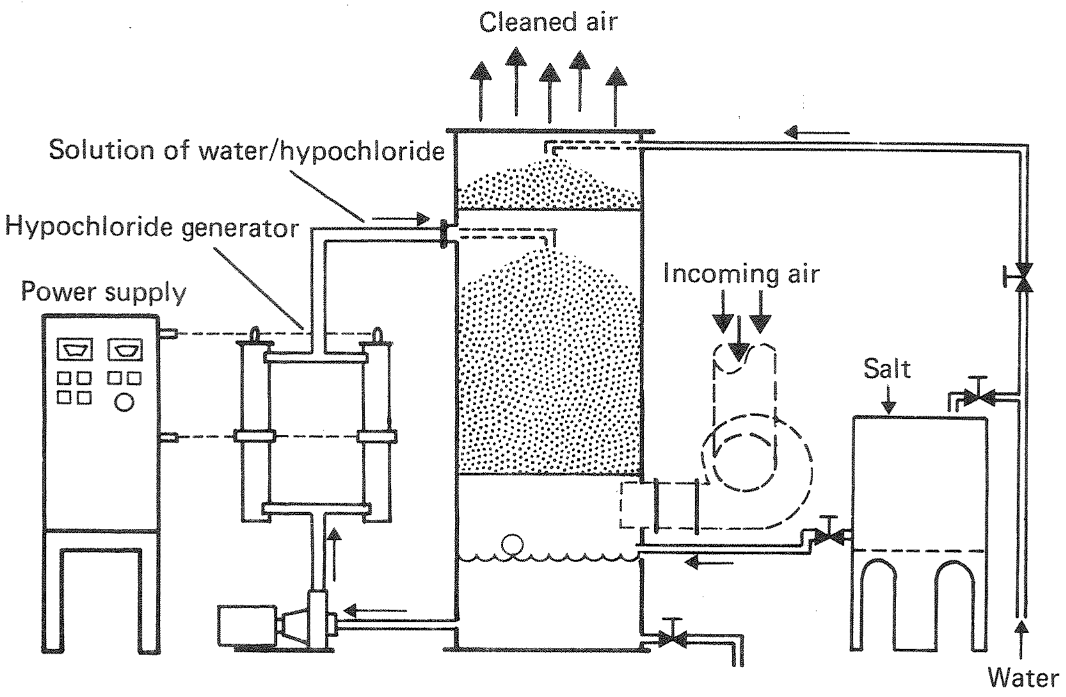

Figure 8.6. Chemical scrubber, type Pepcon.

scrubber, however, is improperly operated, this "scrubber odor" changes to a typical "chlorine odor".

Cost for operating the chemical scrubbers can be divided into chemical cost and cost of energy. Energy will always contribute most to the total cost of operation. For a Pepcon scrubber the energy cost will be approximately 2/3 of the total operational cost.

ACTIVATED CARBON FILTERS

Use of carbon filter for odor reduction is quite common at municipal wastewater treatment plants that receive septage. The odor compounds are not destroyed in the filter, but only retained until the carbon becomes saturated. When the filter is saturated the carbon is changed or regenerated.

Odor strength measurements at different sewage treatment plants in Norway have shown that no rule can be made as to when the change of filters has to take place. During a cold winter longer intervals are possible compared to the warmer seasons.

In Figures 8.7 and 8.8 an activated carbon filter used for cleaning exhaust air from a dewatering process is shown. Together with the carbon, the equipment includes a grease-filter and a condensation unit.

Odor strength measurements indicated reduction efficiencies up to 83 percent when a completely new filter was used. An old filter, which had been used twice as long as the manufacturer had recommended, showed, however, reduction efficiencies of 72 percent.

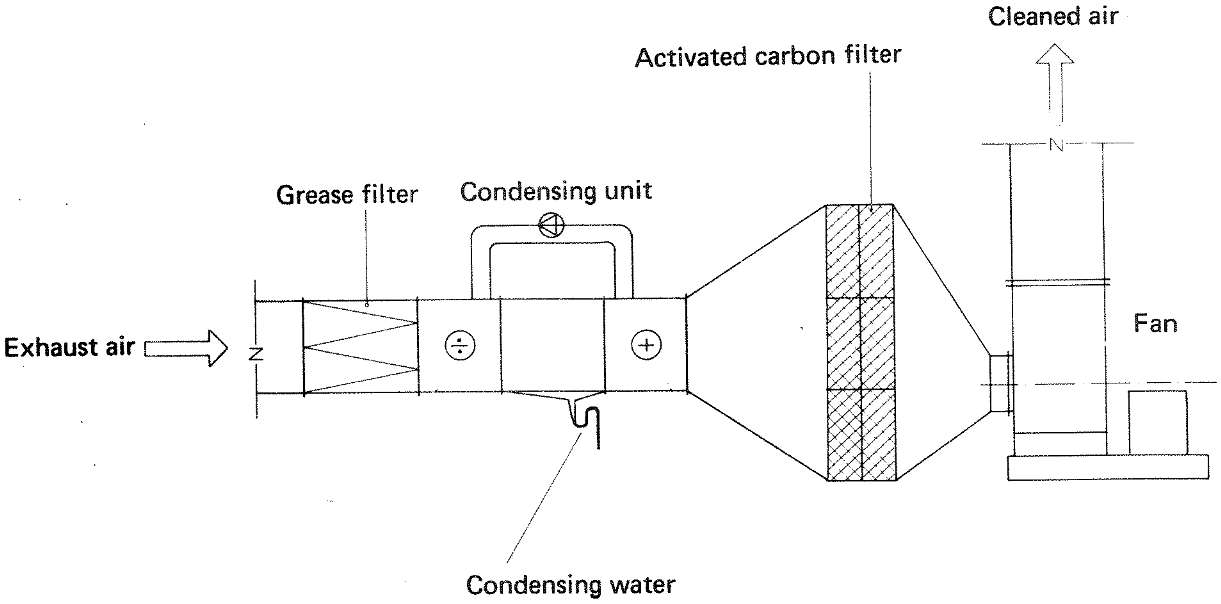

Figure 8.7 Carbon Filter for odor reduction.

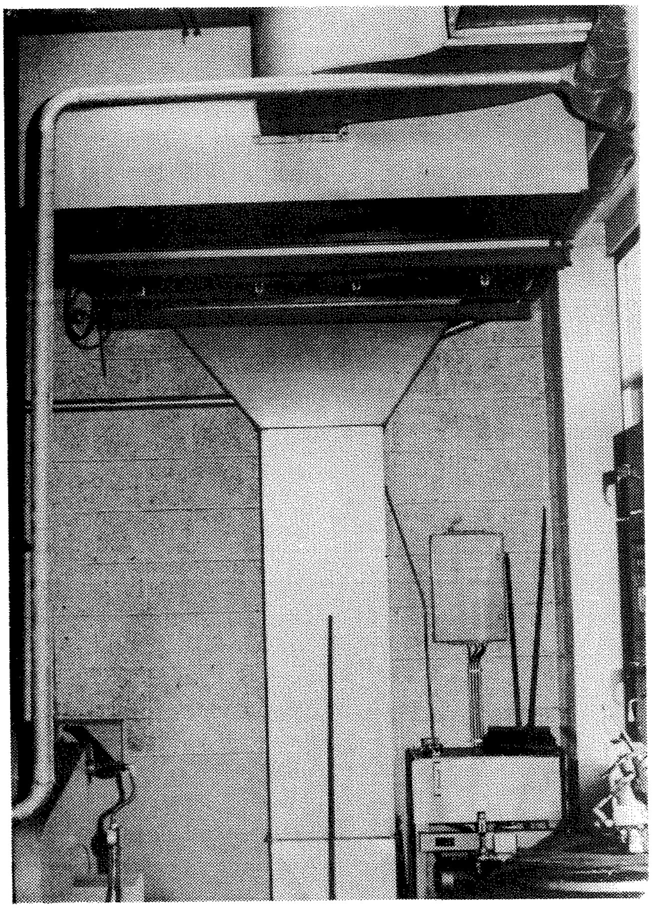

Figure 8.8 Carbon filter at Bekkelaget Treatment Plant.

The cleaned air from the activated carbon unit had a wastewater smell. Evidently not all odor components were destroyed in the filter. When the filter becomes saturated, the components leave the filter as new odorous air reaches the filter.

However, if changes take place too often, the expenses will be high. Our investigations have shown that some filters where the manufacturer had recommended the filter changed 4 times a year, gave almost the same odor reduction efficiencies if the change was made only twice a year.

Because of the above experiences, reducing odor problems from wastewater treatment plants receiving septage by the use of activated carbon filters, is not recommended.

COMBUSTION

The principle of burning odor components to highly oxidized products with little or no odor, is very old. If the temperature and contact time of the gases in the combustion chamber are sufficient, combustion of odor from a sewage treatment plant, without doubt, is the best odor reduction method. Contact time up to 3 seconds and temperatures of about 850 °C have been reported as sufficient. (Pettit, 1959; Laboon, 1961.)

Catalytic oxidation makes it possible to destroy odorous gases at temperatures lower than without catalysts. Low concentrations of odorous compounds and sulfuric odor compounds reduce the effect of the catalyst and thus limit the application of catalytic oxidation for control of odors at wastewater treatment plants.

Another problem with combustion of odorous gases is the rising fuel costs. A special incinerator just to take care of the odors from a treatment plant would not be economical compared to the use of chemical scrubbers. If, however, sludge gas from a digester is available, the fuel costs can be reduced.

The City of Oslo has the only treatment plant in Norway using combustion to reduce odor. The plant has digesters and therefore low fuel costs. The efficiencies measured show a very good odor reduction, up to 98-99 percent. No wastewater odor was recognized in the cleaned air, only a faint "burnt odor".

BUBBLING ODOROUS GASES THROUGH ACTIVATED SLUDGE BASINS

At a small activated sludge plant odor reduction by bubbling the ventilation air into an aeration basin has been attempted. The treatment plant receives septage, and therefore the odor problems had been very offensive prior to odor control. The method is very inexpensive. A fan takes the air from the septage storage tank and blows it into the activated sludge basin.

Odor strength measurements showed an odor reduction efficiency of approximately 90 percent. The cleaned air had a slight smell of sewage. With small alterations; change of the size of the bubbles, change in the mixture of air and odor gases, it is possible that the odor reduction can be improved. It should be mentioned that the method can only be used at activated sludge plants and thus is of limited use in parts of Scandinavia.

BIOLOGICAL METHODS FOR ODOR REDUCTION

Extensive work has been carried out in the US regarding the use of soil filters for odor reduction (Carlson et al., 1964, 1966). It was shown that the filter performance depended on filter loading, type of soil, soil moisture, temperature and concentration of odorous components. The US study also concluded that both chemical and biological processes were responsible for the odor reduction.

In Germany reports have been given describing soil filters treating more than 100,000 m^3 air/h (Pfeiffer, 1981). It was stated that when using these filters care must be taken to have the correct soil temperature and moisture content. In Germany this was taken care of by installing water sprinklers that were activated when the moisture dropped below a certain value.

At a receiving station for septage in Norway a pilot-scale soil filter was tested for one year (Eikum, 1976). At this particular receiving station complants had been made by neighbors because of the odors in the near vicinity of the plant. The soil filter was one of two methods tested at this particular plant.

The test installation is shown in Figures 8.9 and 8.10. After a one-month testperiod the loading was adjusted to approximately 18 $m^3/m^2 \cdot h$. Since the filter was placed outside, approximately 20 meters from the building, the temperature of the filter was dependent upon the outdoor temperature. The building containing the screen and grit chamber was not heated. During the winter the temperature in the filter was below 0 ^oC. Composite samples of H_2S and NH_3 were taken one day each month. During the test-day samples were taken each hour and the average daily concentrations in and out of the filter are shown in Figure 8.11. Both H_2S and NH_3 concentrations were effectively reduced in the soil filter. (See Table 8.2.) During the summer months the filter was not watered in order to see the effect of low humidity in the filter. The removal efficiency dropped during this period, and there was a slight odor out of the filter. The odor intensity was measured with a Scentimeter TM, Model 1959-A. The odor intensity varied during the day. The number given in Table 8.2 gives the number of dilutions necessary before the threshold limit is reached.

Carlson et al. (1966) suggest a loading of 6.2 $m^3/m^2 \cdot h$ when using soil filters for odor reduction. However, the concentrations of H_2S used in his study were higher than at the test site in Norway.

Very limited knowledge is available regarding the life of a soil filter. During the test in Norway no sign of a breakthrough was detected after one year of operation. It is quite possible that the filter regenerates itself during periods when no odorous gases are entering the filter.

Helmer (1974) reported on the use of soil filters for odor reduction. He discussed in detail the removal mechanism taking place in the filter. He pointed out that a breakthrough of odorous gases would occur when either the capacity of the physical removal mechanism of the filter is exceeded or when the gas contains inhibiting or toxic substances that slow down or stop the biological activity. Without the biological activity the filter will not regenerate and its practical use is limited. Helmer noted that 10 mg/l H_2S could be

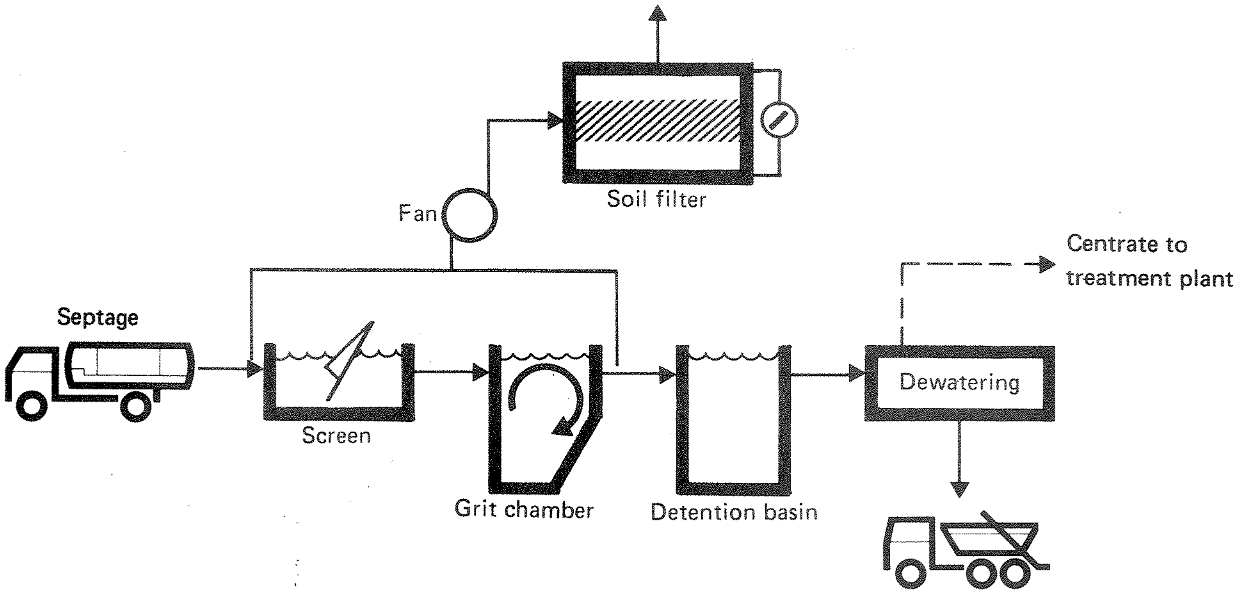

Figure 8.9 Placement of pilot-scale soil filter at TAU Treatment Plant in Tønsberg, Norge (Eikum, 1976).

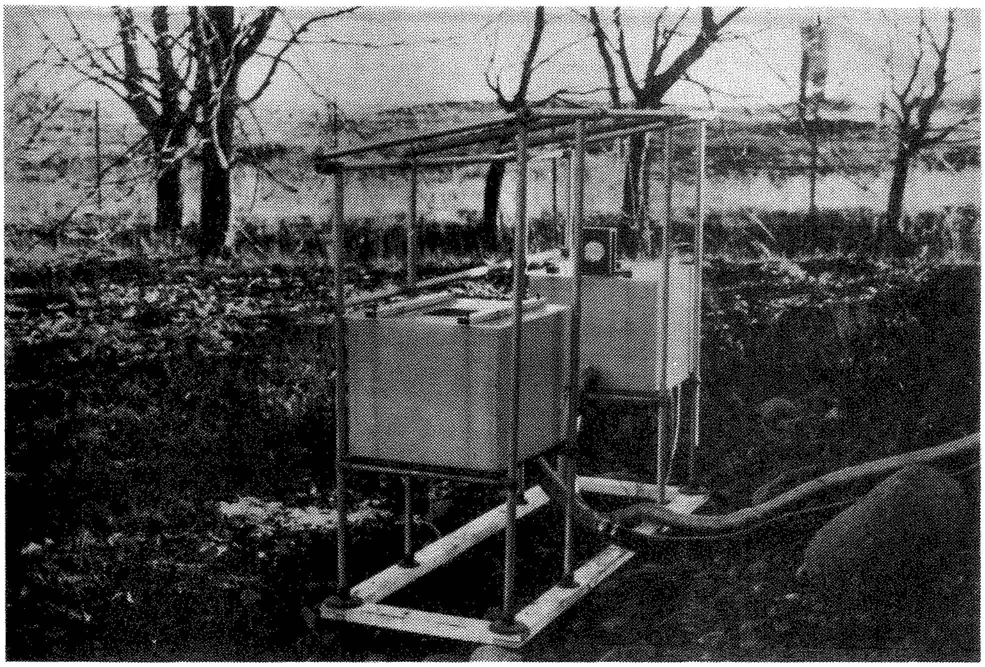

Figure 8.10 Pilot-scale soil filter at TAU Treatment Plant in Tønsberg, Norway (Eikum, 1976).

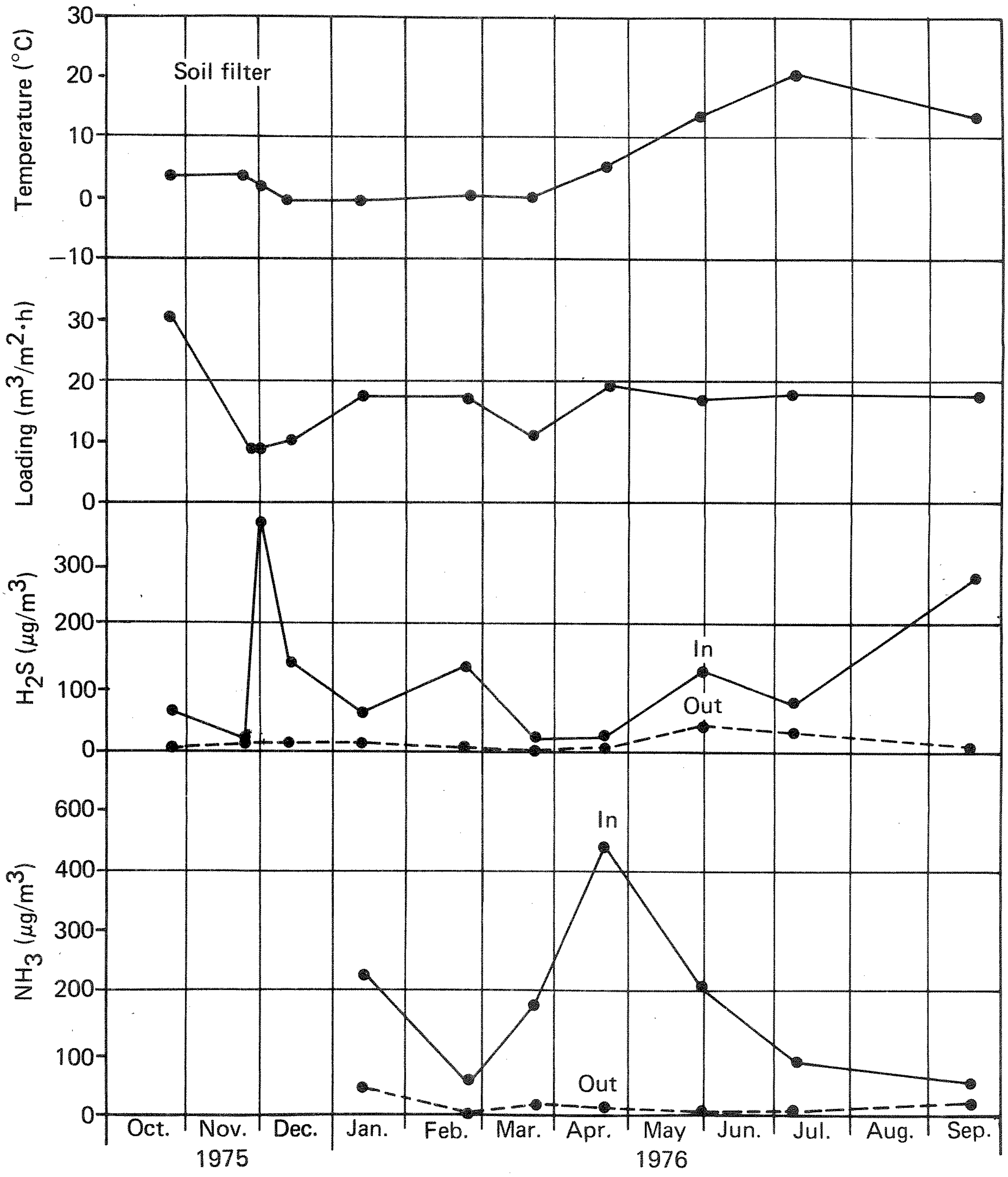

Figure 8.11 Odor reduction at receiving station for septage using soil filter (Eikum, 1976).

TABLE 8.2. RESULTS FROM PILOT-SCALE SOIL FILTER FOR ODOR REDUCTION AT RECEIVING STATION FOR SEPTAGE (Eikum, 1976)

Date	Temp. in the filter	Capacity	Hydrogen sulfide concentr.			Ammonia concentration			Odor intensity	
			$\mu g/m^3$ H_2S			$\mu g/m^3$ NH_3				
	^oC	$m^3/m^2 \cdot h$	In	Out	% red.	In	Out	% red.	In	Out
Oct. 25-75	3.9	30.2	59.4	<0.69	98.8	-	-	-	-	-
Nov. 25-75	4.0	8.4	15.2	-	-	-	-	-	-	-
Dec. 1-75	2.0	9.7	378.9	0.90	99.8	-	-	-	350*	-
" "	-0.1	10.2	139.9	0.94	99.3	-	-	-	31	ND**
Jan. 12-76	-1.0	17.2	54.2	4.10	92.4	225.9	46.2	89.2	-	ND
Feb. 24-76	0.2	17.0	130.5	0.0	100	52.4	3.2	93.9	170	ND
Mar. 23-76	-0.1	10.9	9.7	0.0	100	182.4	16.8	90.8	-	ND
Apr. 21-76	5.6	19.8	17.2	2.0	88.4	439.2	-	-	-	-
May 31-76		17.7	124.4	39.5	68.2	199.0	7.9	96.0	170	7
July 7-76	20.8	18.5	74.0	21.7	70.7	85.0	8.6	89.9	-	-
Sept.20-76	13.1	17.6	279.0	3.3	98.8	47.3	28.2	40.4	-	-

* Indicates dilutions necessary before odor is not detectable.

** ND = not detectable.

completely removed by a soil filter. Removal rate for methylmercaptan was estimated to be 1.0 mg/μg TSS·h. The capacity of the soil filter for ammonia removal was also found to be very good, due to microbial nitrification. The removal of organic substance was estimated by Helmer to be approximately 100 mg/μg TSS·h.

Helmer (1974) also tested the use of compost rather than soil in the filter. He concluded that compost can be used as filter media. In Table 8.3 the loading and detention time used in different investigations are shown.

TABLE 8.3. DESIGN PARAMETERS FOR SOIL FILTERS USED FOR ODOR REDUCTION

Refr.	Facility	Air loading rate ($m^3/m^2 \cdot h$)		Detention time (sec.)
		Soil	Compost	
Carlson et al. (1966)	Test	6	-	500
Helmer (1974)	"	-	1.4	30-100
Eikum (1976)	"	18	-	80
Mayo (1962)	Full scale	35-90	-	20-40
Frechen (1967)	"		45	75

Eikum (1976) concluded in his study that a soil filter treating odors from a wastewater treatment plant with septage handling should not be designed with a detention time of less than 30 seconds.

At TAU Treatment Plant in Tønsberg, Norway, a full-scale soil filter was put into operation in the summer 1981. The filter treats odors from the receiving facility for septage only. This facility handles 14,000 m^3 of septic tank pumpings annually. It consists of screening, grit removal, a storage basin, and dewatering equipment. The fan inlet is located at the end of the storage basin so that the odorous air is evacuated through the screen and grit removal room and into the storage basin. The fan blows the air either through the soil filter (normal operation) or through the chimney (in case filter media must be changed).

The filter consists of 35 m^2 of filter area, 0.5 m thick. The air is distributed through a diffusor system with a 400 mm header pipe with twelve mm laterals. The pipes are located in the gravel layer. The air flow through the filter is 2000 m^3/h under constant operation. When a tank truck empties septage at the plant, the screen automatically goes into operation, and the fan speed increases to a capacity of 3,000 m^3/h. When the screen stops, the fan capacity is again reduced to 2,000 m^3/h. The filter loading therefore varies between 57 $m^3/m^2 \cdot h$ and 86 $m^3/m^2 \cdot h$. The filter design is shown in Figures 8.12, 8.13 and 8.14.

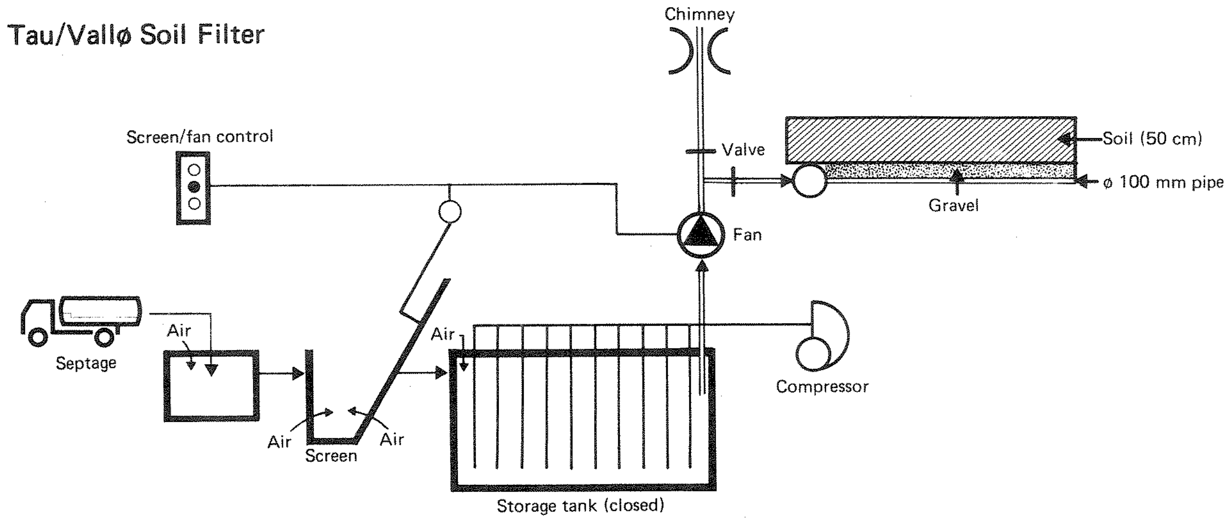

Figure 8.12. Full-scale soil filter at TAU Treatment Plant, Tønsberg. Norway.

So far no odors have been detected out of the filter. Regarding longterm performance it is too early to draw any conclusions.

IRON OXIDE FILTERS FOR ODOR REDUCTION

Only limited information is available regarding the design and use of iron oxide filters for odor reduction, although Cormack et al. (1974) describe the filters in their work. Eikum (1976) studied the use of an iron oxide filter at the same receiving facility for septage as shown in Figure 8.9. The filter media was wood chips mixed with 0.2 kg Fe_2O_3 per kg chips. The depth of the filter was 0.4 meter. The loading of the filter was approximately 16-18 $m^3/m^2 \cdot h$ except for the first few months in the one-year testperiod.

Chemical processes are primarily resonsible for the odor reduction taking place in the iron oxide filter. It is assumbed that the removal of H_2S follows the reactions:

$$Fe_2O_3 + 3H_2S \text{ ----> } Fe_2S_3 + 3H_2O$$

The reaction shows that the filter capacity is gradually used up. However, during periods with no odor components an oxidation can take place in the filter, as shown in the equation:

$$Fe_2S_3 + 1.5\ O_2 \text{ ----> } Fe_2O_3 + 3S$$

Figure 8.15 shows high removal of H_2S and NH_3 throughout the test period. The NH_3 removal, which is highly dependent upon the humidity of the filter, decreased during the dry summer months. No water was added to the filter. The odor intensity measured out of the filter was so low that it was not possible to detect any odor except the slight "wood odor" from the wook chips. (See Table 8.4.)

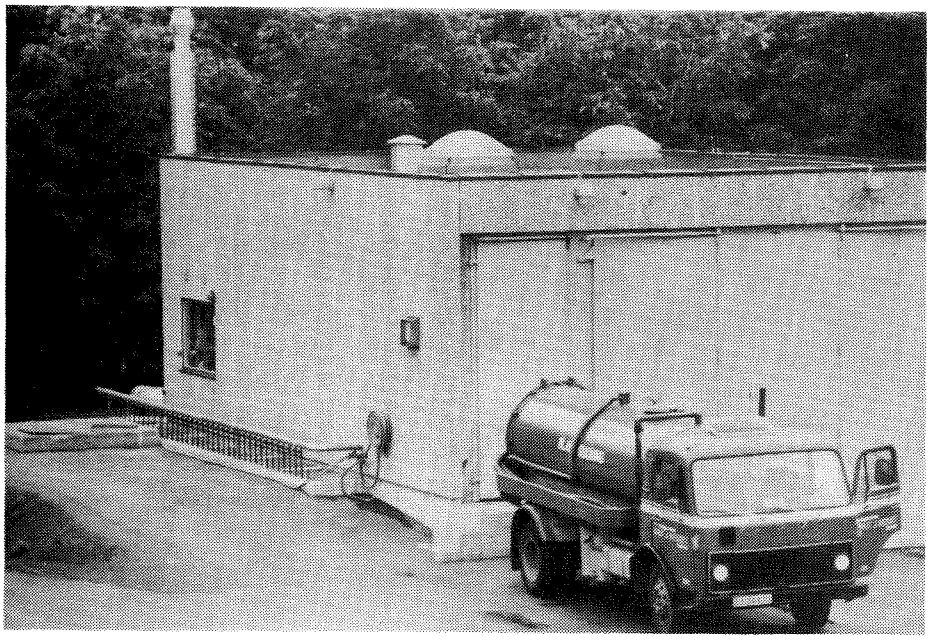

Figure 8.13 Soil filter is located behind the building. Chimney (for bypass only) extends above roof.

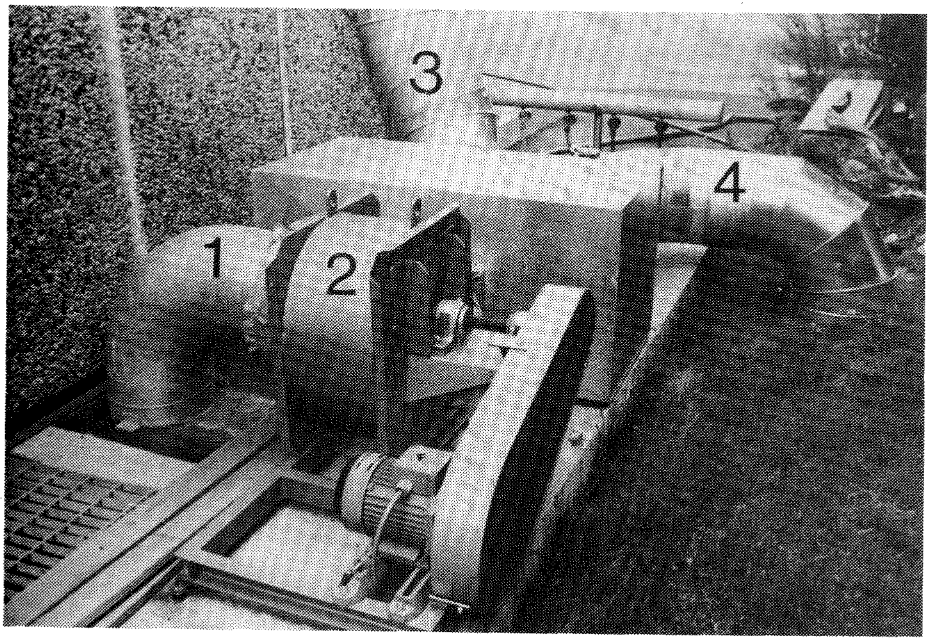

Figure 8.14 Machinery is located outside. (1 odorous gas inlet, 2 fan, 3 bypass pipe to chimney, 4 pipe to soil filter).

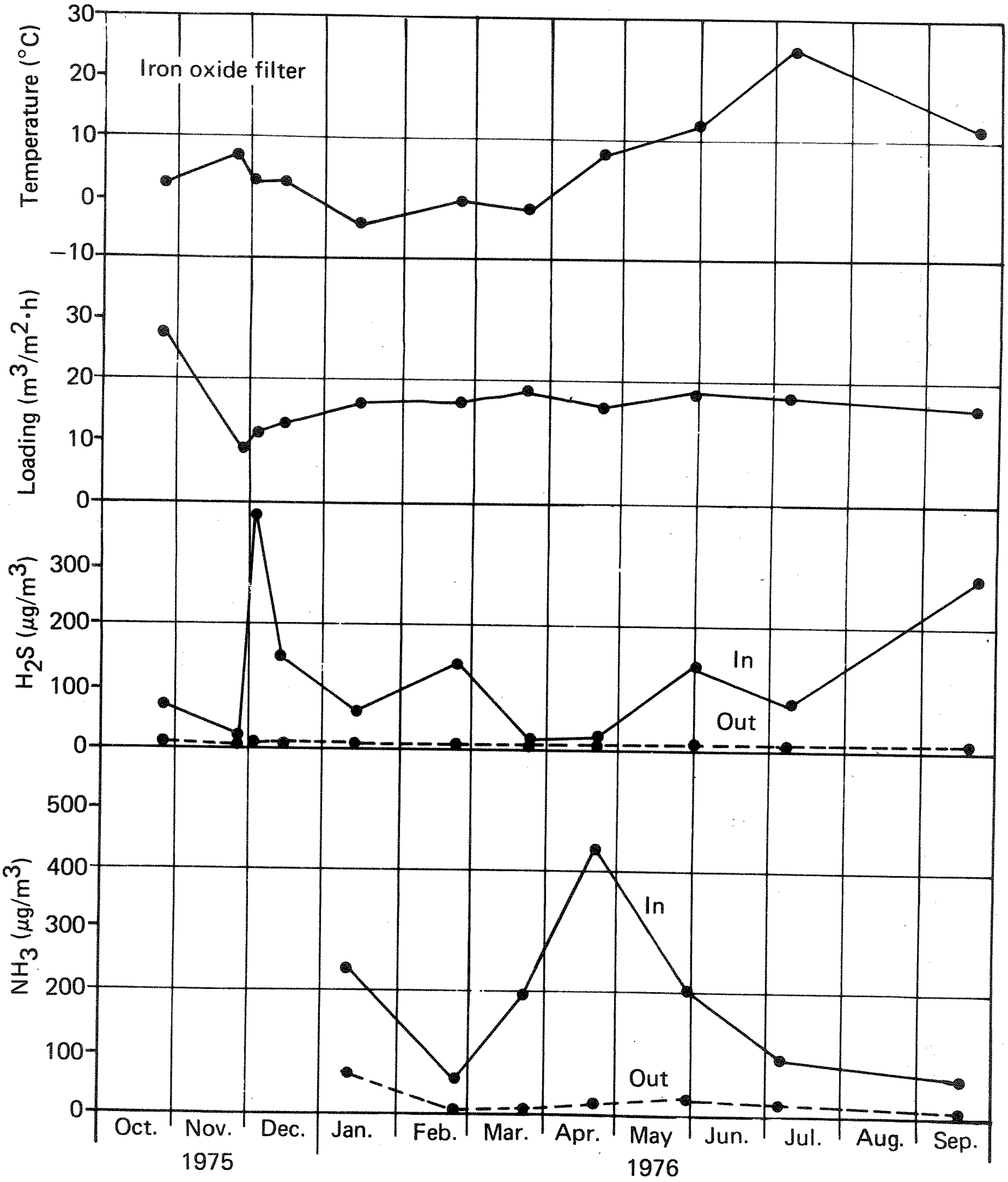

Figure 8.15 Odor reduction at a receiving station for septage using iron oxide filter (Eikum, 1976).

TABLE 8.4. RESULTS FROM PILOT-SCALE IRON OXIDE FILTER FOR ODOR REDUCTION AT RECEIVING STATION FOR SEPTAGE (Eikum, 1976)

Date	Temp. in the filter	Capacity	Hydrogen sulfide concentr.			Ammonia concentration			Odor intensity	
			µg/m H_2S			µg/m NH_3				
	^oC	$m^3/m^2 \cdot h$	In	Out	% red.	In	Out	% red.	In	Out
Oct. 25-75	2.9	27.3	59.4	<0.64	98.9	-	-	-	-	-
Nov. 25-75	6.5	8.4	15.2	1.33	91.3	-	-	-	-	-
Dec. 1-75	2.0	10.7	378.9	<0.90	99.8	-	-	-	350*	ND**
" "	3.1	12.8	139.8	0.74	99.5	-	-	-	31	ND
Jan. 12-76	-3.5	16.2	54.2	4.10	92.4	225.9	65.0	71.2	-	ND
Feb. 24-76	1.8	16.6	130.5	0.0	100	52.4	3.7	92.9	170	ND
Mar. 23-76	-1.5	18.5	9.7	0.55	94.3	182.4	0.61	99.7	-	-
Apr. 21-76	8.0	16.8	17.2	1.36	92.1	439.2	-	-	-	-
May 31-76	13.5	18.5	124.4	2.1	98.3	199.0	24.0	87.9	170	ND
July 7-76	25.0	18.5	74.0	3.3	96.0	85.0	-	-	-	-
Sept.20-76	13.2	16.8	279.0	0.5	99.8	47.3	15.0	68.0	-	-

* Indicates dilutions necessary before odor is not detectable.

** ND = not detectable.

The City of Oslo built an iron oxide filter at its Festningen Treatment Plant. The filter is shown in Figures 8.16 and 8.17. The untreated air is taken from a closed compartment above a sludge storage basin. The filter was designed for a maximum capacity of 90 $m^3/m^2 \cdot h$, but the actual loading can vary between 20 and 90 $m^3/m^2 \cdot h$. The total filter area is 9 m^2 and the media consists of 900 kg Fe_2O_3 mixed with 4 m^3 wood chips.

The ED_{50} was tested through a 4-month period. Prior to this testing period the filter had been in operation for four months. The test results are shown in Table 8.5.

The loading of the filter was increased during the test period with the surprising result that the removal efficiency increased. The reason for this is that at low loadings the "filter media odor" is very strong and this gives a high ED_{50} value out of the filter. As the loading increases, a flushing effect takes place with the result that the odor from the filter media decreases. High removals were found even with a loading of 250 $m^3/m^2 \cdot h$.

TABLE 8.5. REMOVAL EFFICIENCY OF ODORS vs. FILTER LOADING FOR IRON OXIDE FILTER AT FESTNINGEN TREATMENT PLANT (Berg, 1979)

Date 1979	Loading $m^3/m^2 \cdot h$	ED_{50} In	ED_{50} Out	Removal efficiency %
Jan. 1	20	3200	1250	61
" "	60	2800	1050	63
" "	90	2900	550	81
April 4	20	1300	325	75
" "	60	1450	270	81
" "	90	1400	250	82
April 24	90	2800	520	82
" "	180	3100	570	82
" "	250	2950	340	89

In Tønsberg, Norway, an iron oxide filter was constructed to reduce odors from a pumping station close to the municipal treatment plant. The filter is shown in Figure 8.18. The filter treats odors caused by evacuation of air from a pressure main. The air enters the filter through a perforated pipe at the bottom and flows through the filter media into the atmosphere. The filter has been in operation since the summer of 1978. Tests of the filter performance have been carried out regularly since then.

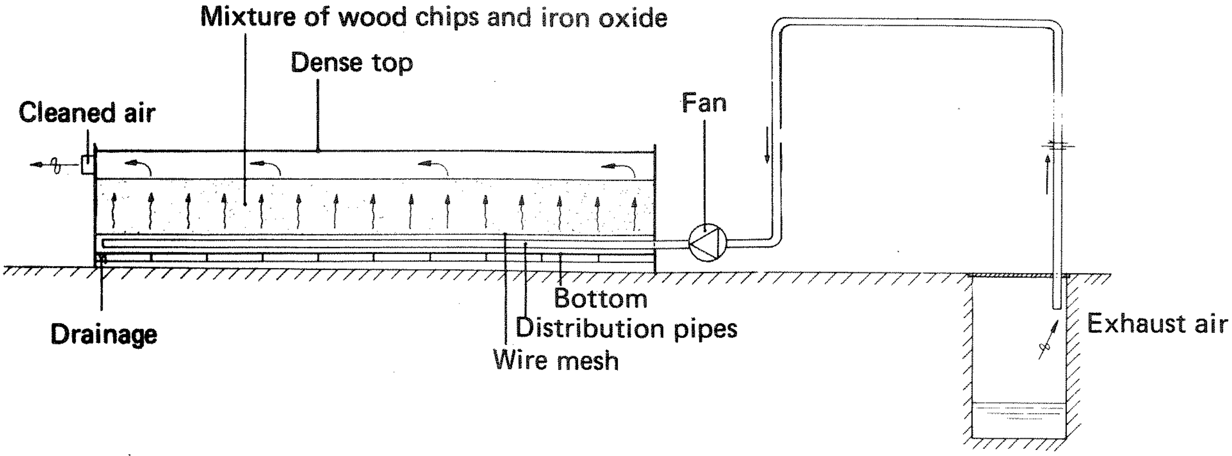

Figure 8.16. Iron oxide filter design at Festningen Treatment Plant, Oslo, Norway.

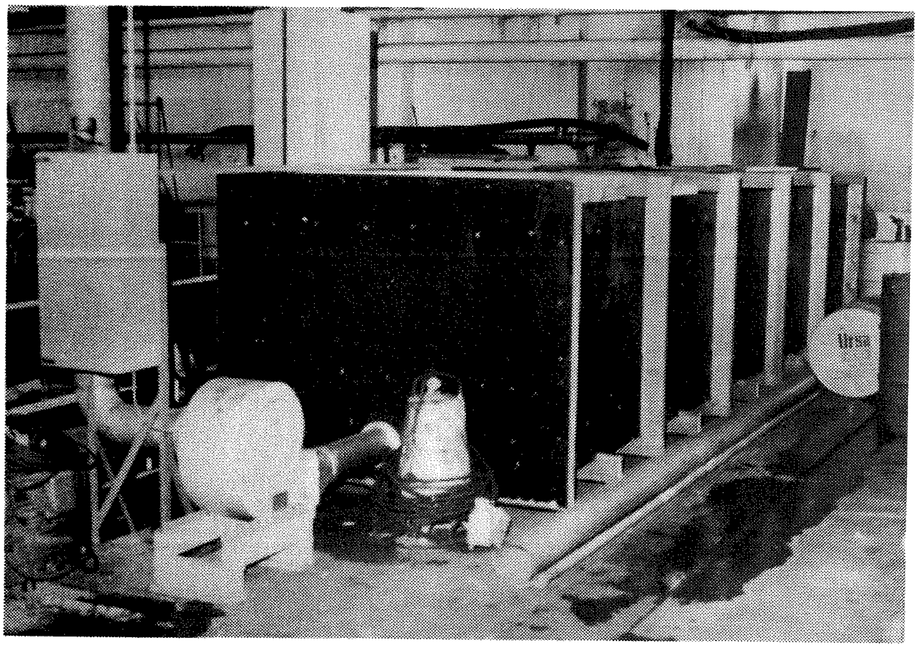

Figure 8.17. Iron oxide filter at Festningen Treatment Plant, Oslo, Norway.

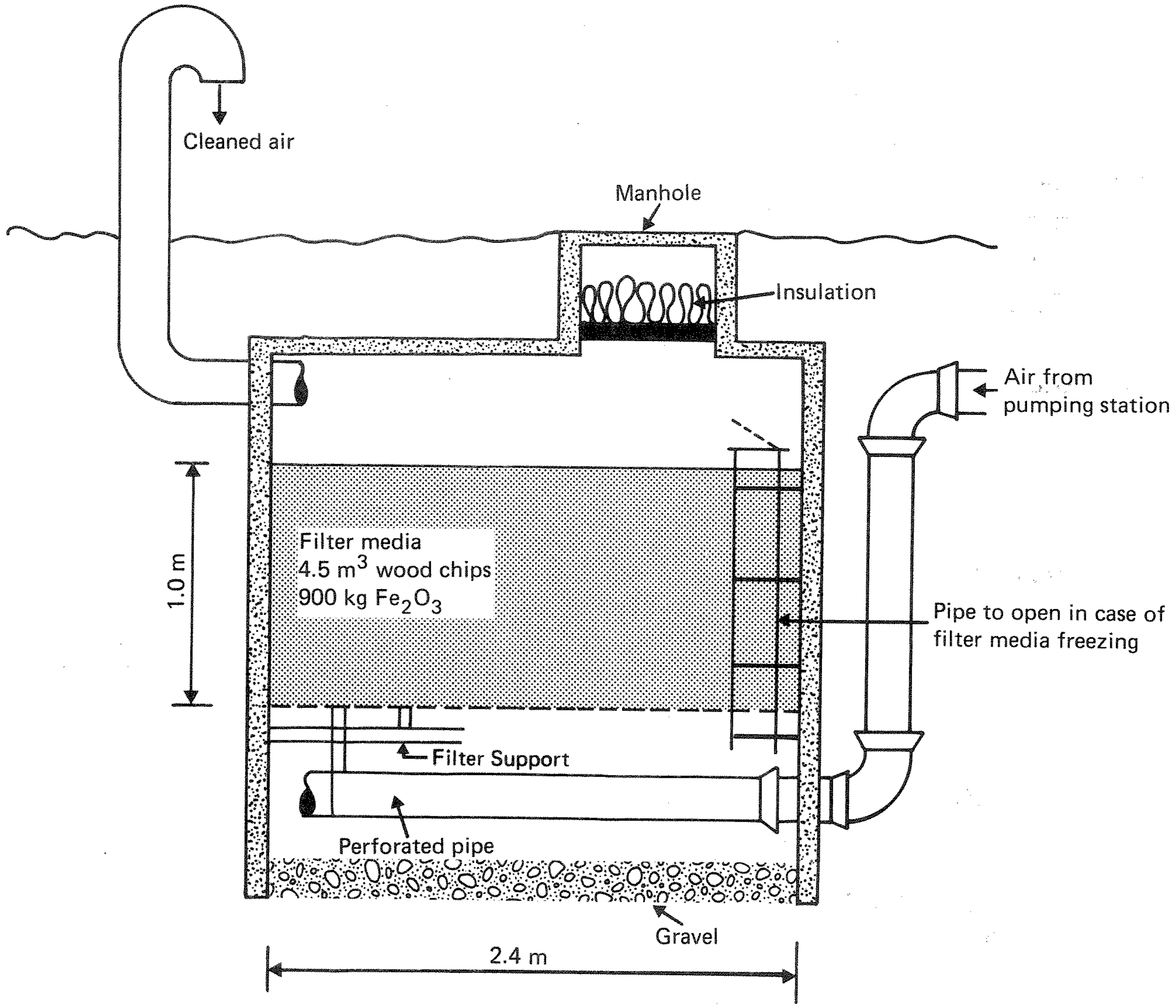

Figure 8.18. Iron oxide filter in Tønsberg, Norway.

The filter loading varies between 870 m^3/h and 1140 m^3/h. Based on the filter surface of 4.5 m^2 the surface loading is 193-253 $m^3/m^2 \cdot h$. When the pumps stop, fresh air is sucked through the filter in reverse. This probably helps regenerate the filter and thus lengthens its service life, as described earlier. The odor reduction efficiencies measured are shown in Table 8.6.

The removal efficiency during 1979 was satisfactory. The odors in the untreated air were moderate (ED_{50} approximately 600), and the odors out of the filter were characterized by the panelists as the odor from the wood chips. In August 1980 the odors in the untreated air increased considerably due to warm weather and long detention times in the pressure main. The removal efficiency dropped to 55 percent. The filter capacity was exceeded. In the spring of 1981 the filter media was changed and the filter performance was restored. (Mollatt, 1981.)* The pumping station is located in a residential district, and

* Personal communication.

TABLE 8.6. IRON OXIDE FILTER PERFORMANCE, TØNSBERG, NORWAY

Date	ED_{50}		Removal efficiency
	In	Out	%
Feb. 1979	480	125	74
"	540	160	70
Nov. 1979	600	70	88
"	650	70	89
Aug. 1980	7500	3400	55

before the iron oxide filter was installed, there were frequent complaints from residents in the area. After the filter was installed, the complaints ceased completely.

OTHER ODOR REDUCTION METHODS

Many wastewater plants reduce offensive odors by use of ozone, oxygen, H_2O_2, chlorine gas, addition of metallic ions to form insoluble sulfides, odor counteraction, or odor masking. Since none of these methods are known to be used for odor reduction in connection with septage treatment in Scandinavia, they will not be further discussed.

CONCLUSIONS

Odor problems at treatment plants can be solved with existing technology. However, much money can be saved if the odor problems are solved on the drawing board rather than as a retrofit measure made necessary by the pressure from the residents living in the vicinity of the plant.

It is very important to identify the main sources of odor and treat the odorous air separately. This will reduce the volume of air to be treated and thus the overall cost.

The different methods for odor reduction should be considered. The relatively natural technologies like soil or iron oxide filters are methods to be considered alongside the more advanced methods like chemical scrubbers, incineration, etc.

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SECTION 9

MOBILE SEPTAGE DEWATERING

As an alternative to septage treatment at a wastewater treatment plant, a mobile dewatering unit was recently introduced in Scandinavia. There are several potential advantages of such a sceme:

1. Reduced overall septage volume for treatment and ultimate disposal.
2. Lower sludge production at the treatment plants due to lower solids content in the filtrate.
3. Lower costs for transportation.
4. Higher capacity. On-the-road dewatering increases the number of septic tanks that can be visited before disposal. Filtrate may be returned to the septic tanks.
5. Reduced labor because higher degree of automation and remote control enables one man to operate the equipment.
6. Reduced health risk due to fewer operational steps in the septage handling process and lime conditioning.

TECHNICAL DESCRIPTION

Figure 9.1 indicates the major components of the truck. The mobile unit consists of a vacuum filter which differs from conventional design. The filter will be further discussed below. The tanks include a 4.5 m^3 storage tank for conditioned septage, one for filtrate, a 3 m^3 sludge cake container, and a lime-powder container. The hose feed, sludge suction and conditioning can be remotely operated from a control panel worn on the belt of the operator. The unit is mounted on a 22 (metric) ton truck. A 35 kW diesel engine supplies power to vacuum pumps and filter. The hose length is 90 m on a motor windlass.

OPERATIONAL PROCEDURE

The sequential steps in septage collection and dewatering after gaining access to a septic tank (Figure 9.2) are listed below.

1. Preparations and unwinding of the hose from the windlass.
2. Suction of contents from the tank. Suction can be facilitated by periodically blowing air or filtrate into the septic tank to mix or liquify the contents. The septage is conditioned with lime fed in-line before it enters the storage tank.
3. Filtrate return. After completed septage suction, the filtrate from the previous dewatering operation is emptied by applying positive pressure and returning the filtrate to the empty septic tank.
4. Dewatering of conditioned septage from the storage tank begins while the hose is being retracted and the unit moves off to the next collection site. The filtrate tank is gradually filled as dewatering progresses, correspondingly emptying the septage storage tank.

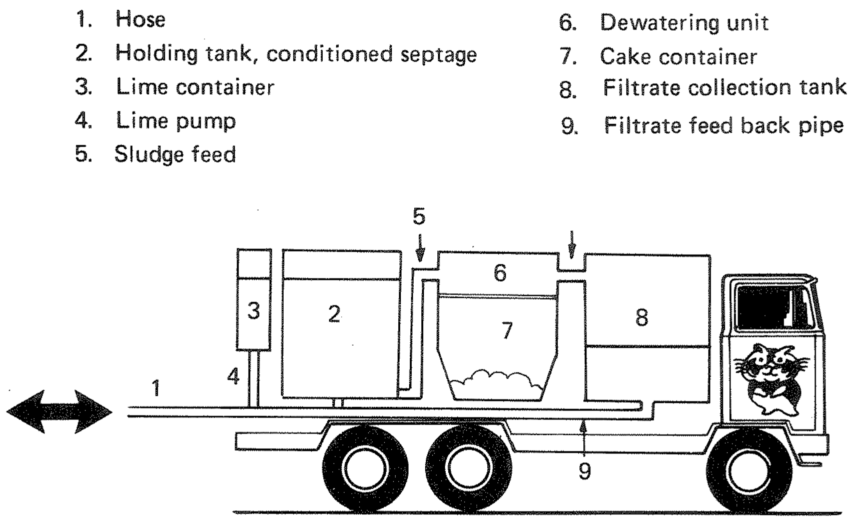

Figure 9.1. The different equipments of the mobile dewatering unit.

DEWATERING EQUIPMENT

Dewatering is performed with a "vacuum press" designed to handle non-homogeneous septage. Figure 9.3 shows the press which consists of two parallel rollers held together by high pressure.

The rollers are made of perforated steel, covered with rubber and a steel mesh to cushion and distribute stress. When the filter picks up solid material, the surface of the rollers will yield to let the lumps pass between the rollers. The rollers are suspended by hydraulic cylinders supplying the pressure between the rollers and also additional flexibility when solid material passes through the press area. The rollers are covered with filter-cloth.

The rollers are 50 percent submerged in the reservoir and pick up a layer of solids by suction. The cake is pressed as it passes between the rollers. The suction is released from the forward roller and the cake from this cylinder attaches to the cake already formed on the rear cylinder. The sandwiched cake is then blown off the rear roller as it reaches a scraper. The cake falls off the scraper into a container.

Occasional manual attendance is required for adjustment of lime feed rate, roller rotation, and cake compression force.

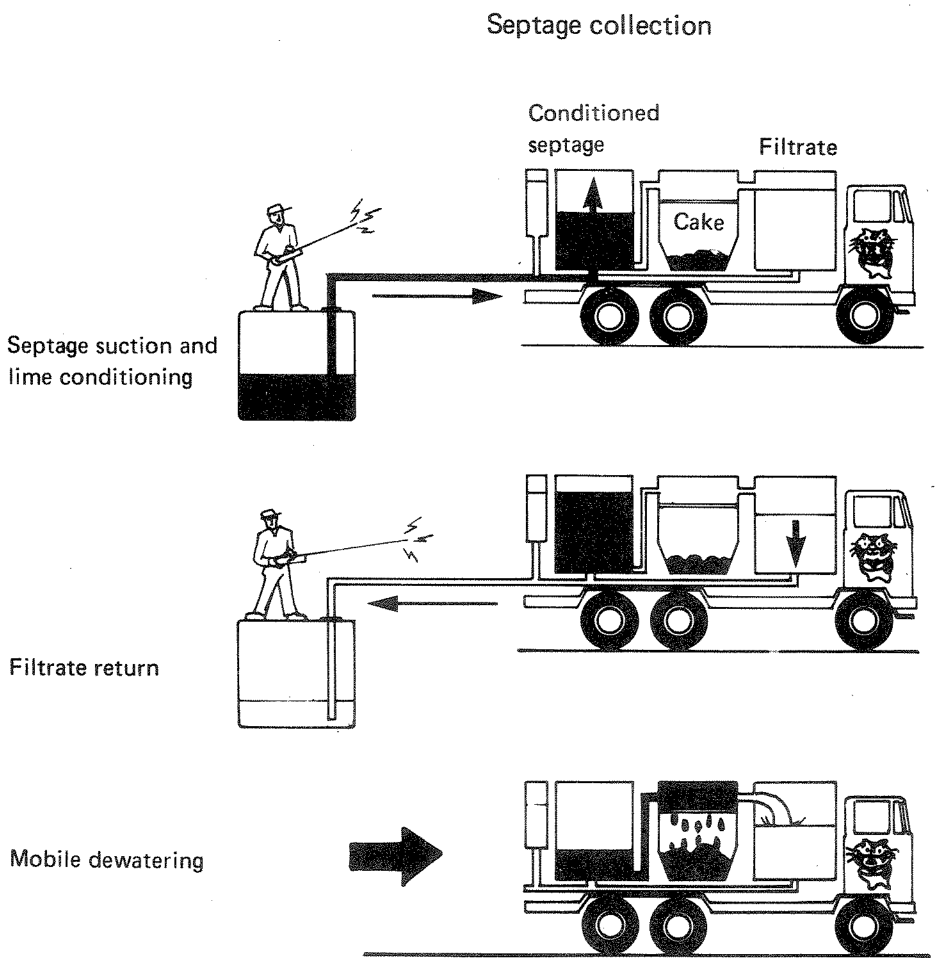

Figure 9.2. Sequential steps in septage collection and on-the-road dewatering.

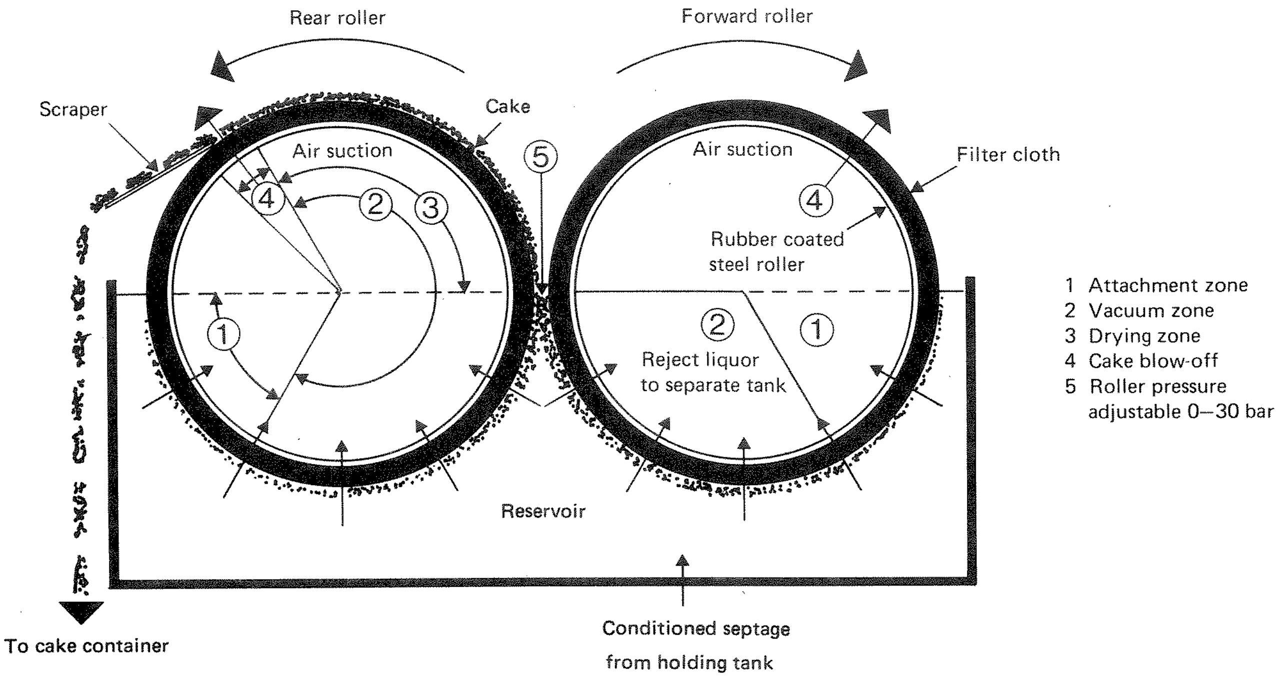

Figure 9.3. Vacuum filter for septage dewatering.

CONDITIONING

Conditioning is accomplished by feeding dry lime ($Ca(OH)_2$) into the suction pipe. Typical doses range from 20 to 40 percent based on the dry solids content of the septage. This gives the septage a pH between 12 and 13.

PERFORMANCE

Results from tests in Norway and Sweden are given in a separate paragraph below. On site time consumption varies little from that experienced in conventional collection. Typical on site operation times are:

Arrival and preparations	5-10 min
Suction	2-6 min/m^3
Filtrate return	3 min
Hose retraction and preparations to leave	5-10 min
Total on site time	20-40 min.

Dewatering proceeds simultaneously to hose retraction, transport to the next site and preparations for the next suction. Dewatering time amounts to 5-10 min/m^3 of septage. Sludge quality and conditioning will determine the rate. Dewatering or transportation will be capacity limiting, depending on dewatering rate and distance to the next collection site.

CAKE AND FILTRATE

The cake holds a dry solids content consistently in the range of 16-23 percent. The high pH due to lime conditioning gives a reduction in counts of pathogenic microorganisms. The filtrate is returned to the septic tanks. Suspended solids content in the filtrate varies considerably, but can be estimated to be 2000-6000 mg/l. Like the feed, the filtrate will have a pH between 12 and 13.

RESULTS FROM TRIALS IN SWEDEN AND NORWAY

The mobile unit has been subjected to full-scale testing in rural and urban areas in Scandinavia. Results obtained in sludge quality and machine capacity depend on local practice regarding collection frequency, septic tank size, etc.

In Uddevalla, Sweden, the truck emptied 146 tanks in 10 days, dewatering 42.1 m^3 sludge per day. Lime consumption amounted to 5.86 kg/m^3 of septage. Time consumption per m^3 of septage was 8.5 min. The study showed a decrease from 11.5 to 7.5 min per m^3 as operation and machine performance were streamlined through the test period. Approximately one hour per day was recorded as "down" time (maintenance, lime -, oil -, and gasoline refill, filter wash).

Tests in Gotland, Sweden, on 85 septic tanks gave a total treatment time of 11.6 min per m^3 of which 7.6 min/m^3 was dewatering. Typical tank size was 3.22 m^3. Nitrogen levels in effluents from the septic tanks were not significantly affected by the filtrate recycled from the truck to the septic tank.

A study in Oslo, Norway, revealed very large variations in capacity, cake and filtrate quality. Table 9.1 shows septage quality and performance obtained with 48 septic tanks. The truck operated in areas where pumping frequency was from one to ten years; septage dewaterability therefore varied considerably. A parallel study on the effect of septage age on dewaterability indicated that the vacuum filtration method employed will benefit if the septage age were kept on the order of 1-3 years.

Poor filtrate quality (Table 9.2) was encountered in instances when conditioning was insufficient or septage contained grease, oil or substances that interfere with filtration. The conclusions drawn from the studies were that mobile dewatering with this machine is an attractive alternative in rural areas, provided:

- Pumping frequency is kept on the order of 1-3 years.
- Septic tanks containing grease or oil are avoided.
- Operation is performed by skilled personnel.
- Disposal sites for high pH sludge cakes can be found.
- Transport distances to treatment facilities are unfavorable to conventional collection.

EFFECT OF FILTRATE ON SEPTIC TANKS

The impact of the returned filtrate was investigated in 6 septic tanks in Sweden. The high pH (12-13) introduced with the filtrate was reduced to normal after 16 days.

TABLE 9.1 DEWATERING OF SEPTAGE WITH MOBILE DEWATERING UNIT (Haugan, 1980).

Tank	Date	TS		Volume cond. septage	Mass cond. septage	Lime used	Dewatering time	Solids recovery	Lime dose $Ca(OH)_2$ in % of TS
		Conditioned septage	Cake						
No.	1980	%	%	l	kg	kg/day	min/m^3	%	%
1	3/5	3.9	17.5	4180	163		-	70	25
2		2.4	18.7	2690	65	25	11.2	-	27
3	3/6	3.2	-	3595	115		8.6	-	15
4		3.7	21.6	2640	98		14.0	92	23
5		4.7	23.1	4370	205	125	-	91	15
6	3/7	10.6	23.3	2875	305	incl.in	16.7	-	-
7		-	-	-	-	3/10	-	-	-
8	3/10	2.3	22.4	2640	61		17.0	-	50
9		3.7	-	2730	101		14.7	-	39
10		4.1	-	2290	94		13.5	-	20
11		2.5	20.4	2730	68		24.2	72	70
12		3.2	15.4	3735	125	325	5.6	52	78
13	3/11	3.2	-	3260	104	incl.in	22.1	-	26
14		1.3	17.8	4370	57	3/12	14.4	-	18
15		-	15.3	3225	-		17.4	-	-
16	3/12	1.8	18.5	2240	40		8.0	79	24
17		6.0	18.6	2785	167		18.0	95	11
18		3.2	15.9	2900	93	150	14.1	-	6
19	3/13	-	-	-	-		-	-	-
20		2.4	21.3	2335	56		24.4	53	19
21		2.1	13.5	2190	46		41.1	18	21
22		-	-	-	-	100	-	-	-
23	3/14	2.6	-	2920	76		8.9	-	24
24		2.8	18.4	4370	122		7.3	85	10
25		1.6	18.5	4370	70		7.3	-	21
26		1.7	16.2	4370	74		5.7	-	25
27		3.3	17.2	4370	144	75	7.1	-	12
28	4/21	3.8	31.6	3850	146		3.4	75	37
29		-	30.7	4370	-		9.2	-	27
30		1.8	23.4	3475	63		2.6	88	25
31		2.5	15.5	4000	100		15.0	73	13
32		1.8	18.7	-	-		-	83	21
33		-	18.8	-	-		-	-	18
34		3.0	13.9	2575	77	100	-	-	23
35	4/22	3.8	16.2	2800	106		14.3	79	39
36		3.9	17.3	2680	105		-	90	25
37		4.9	17.1	2260	111	50	-	-	13
38	4/23	6.0	15.6	3500	210	incl.4/24	-	-	31
39	4/24	2.8	17.7	4370	122		5.0	73	28
40		5.6	12.1	2300	129		31.7	67	40
41		4.5	15.4	1440	65		43.8	87	66
42		3.7	15.3	4100	152	175	25.6	-	88
43	4/25	7.6	18.0	2700	205		33.0	78	51
44		4.1	20.4	2480	102		-	50	50
45		2.3	16.5	2000	46	125	17.0	-	31
46	5/6	5.4	26.5	2480	134		14.9	87	-
47		3.1	21.4	2700	84	-	10.7	74	-
48		4.6	21.9	2450	113		-	-	-
$\bar{x} \pm s$		3.47±1.3	18.7±4.2	2829±1081	112±50		15.6±10		30.2

TABLE 9.2 FILTRATE CHARACTERISTICS (Haugan, 1980).

Septic tank No.	pH	TSS mg/l	TVSS % of TSS	COD mg O/l	Calcium mg Ca/l	Alkalinity mg/l as $CaCO_3$
1		13,740	53			
2		-	-			
3	12.4	4,940	54.7	29,200		
4	12.5	3,460	45.1	9,450		
5	12.5	5,110	47.7	21,700		
6	12.5	-		64,400	1,024	
7		-				
8		-				
9						
10	12.5	6,570	39.6			
11	12.4	7,780	51.1			
12	12.6	17,390	52.8		2,470	4.10
13	12.5	7,920	41.4	20,500	1,280	2.38
14	12.0	-	-	8,225		
15	12.5	7,880	55.3		1,090	1.91
16	12.6	4,100	49.1	12,975	838	1.61
17	12.5	4,100	38.5	58,500	1,022	2.21
18		-	-	39,500		
19		-	-			
20	12.5	11,910	53.7	24,700	1,660	2.63
21	12.5	17,560	50.8	19,000	2,020	3.40
22	12.5	1,140	31.4		619	1.21
23	12.6	1,140	44.9	18,400	643	1.29
24	12.5	4,970	51.2	26,100	938	1.83
25		-	-	12,925		
26		-	-	9,975		
27		-	-	7,825		
28	12.5	10,343	26.3			2.56
29	12.5	15,076	30.5			3.18
30	12.5	2,235	45.3			1.35
31	12.3	7,553	67.9			1.28
32	12.3	3,381	73.7			0.91
33	12.4	4,583	67.8			1.15
34	-	-				
35	12.5	9,626	40.8			2.68
36	12.5	4,978	51.0			1.68
37	-	-	-			
38	-	-	-			
39	12.5	8,638	40.6			2.74
40	12.4	27,063	40.4			5.32
41	12.5	7,941	29.4			3.00
42	11.3	30,700	29.3			8.64
43	12.4	24,460	34.1			6.08
44	12.5	22,885	35.6			5.58
45	-	-	-			
46	12.0	8,698	27.5			3.11
47	12.4	8,876	35.2			2.85
48	-	-				
$\bar{x}$	12.5	10,058	45.0	23,960		

Suspended solids in effluents from the septic tanks after filling with filtrate showed values from 200 to 500 mg/l 3 days after filtrate input. The SS values decreased to less than 200 mg/l in 16 days.

Phosphorus levels in effluents were generally lowered by 30-50 percent compared to values prior to septage removal. This was in part due to some precipitation occurring while the septic tank was still enriched with high pH filtrate. The effect persisted through a 28-day follow-up period. Calcium levels in the effluent increased from an initial value of 150 mg/l to 225 mg/l, but decreased to background level within 7 days.

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