HELSINGE SLUDGE REED BED SYSTEM

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ABSTRACT

The Helsinge sludge reed bed system was established and the reeds planted in October 1996. The reed bed system has a capacity of 630 TDS per year and consists of 10 basins, each having an area of1,050m^2 at the filter surface and a maximum area loading rate of 60 kg DS/m^2/year. Annual sludge production amounts to 550 - 600 TDS. The loading regime of the system consists of applications of approximately 130-150 m^3 of sludge once or twice daily, the feed concentration being approximately 0.5-0.8 % DS. During commissioning (1996-1998), the quota was increased from approximately 200 to 1,000m^3. From 2000, each basin was subjected to a loading quota of 1,500m^3 over a period of approximately 7-8 days. Loading was followed by 45-65 rest days. The loading quota was adjusted by a factor of 10 during the 10-year operating period. After 1998, individual basins were subjected to an average loading rate of approximately 55-65 TDS per year, resulting in an average area-specific loading rate of 55-64kg DS/m^2/year. The sludge residue height increased in the periode from 1998 to 2005 by 1.20 m, and the total sludge residue height by April 2006 was 1.40m. The plan is to empty the Helsinge sludge reed bed system over a 5-year period, with 2 out of 10 basins selected for emptying per year. Capacity during the emptying period will be maintained at 630 tons of dry solids per year

KEY WORDS

Biosolids, Emptying, Enhanced treatment, Loading cycles, Pathogen removal, Reed beds, Sludge dewatering, Sludge quality

TREATMENT PLANTS, WASTE WATER, AND SLUDGE TREATMENT

In 2006, the municipality of Helsinge has five municipal wastewater treatment plants, all mainly treating wastewater from residential areas. The treatment plants were all established and operating prior to 1992 (Table 1). In addition, the waste water system consists of 315 km. of pipelines and approx. 102 pumping stations. Smaller towns in the municipality have combined sewage systems, while Helsinge itself is partially (approx. 40%) served by a separated system. Wastewater treatment uses both iron and aluminium as precipitating agents for the removal of Phosphor. (Table 1)

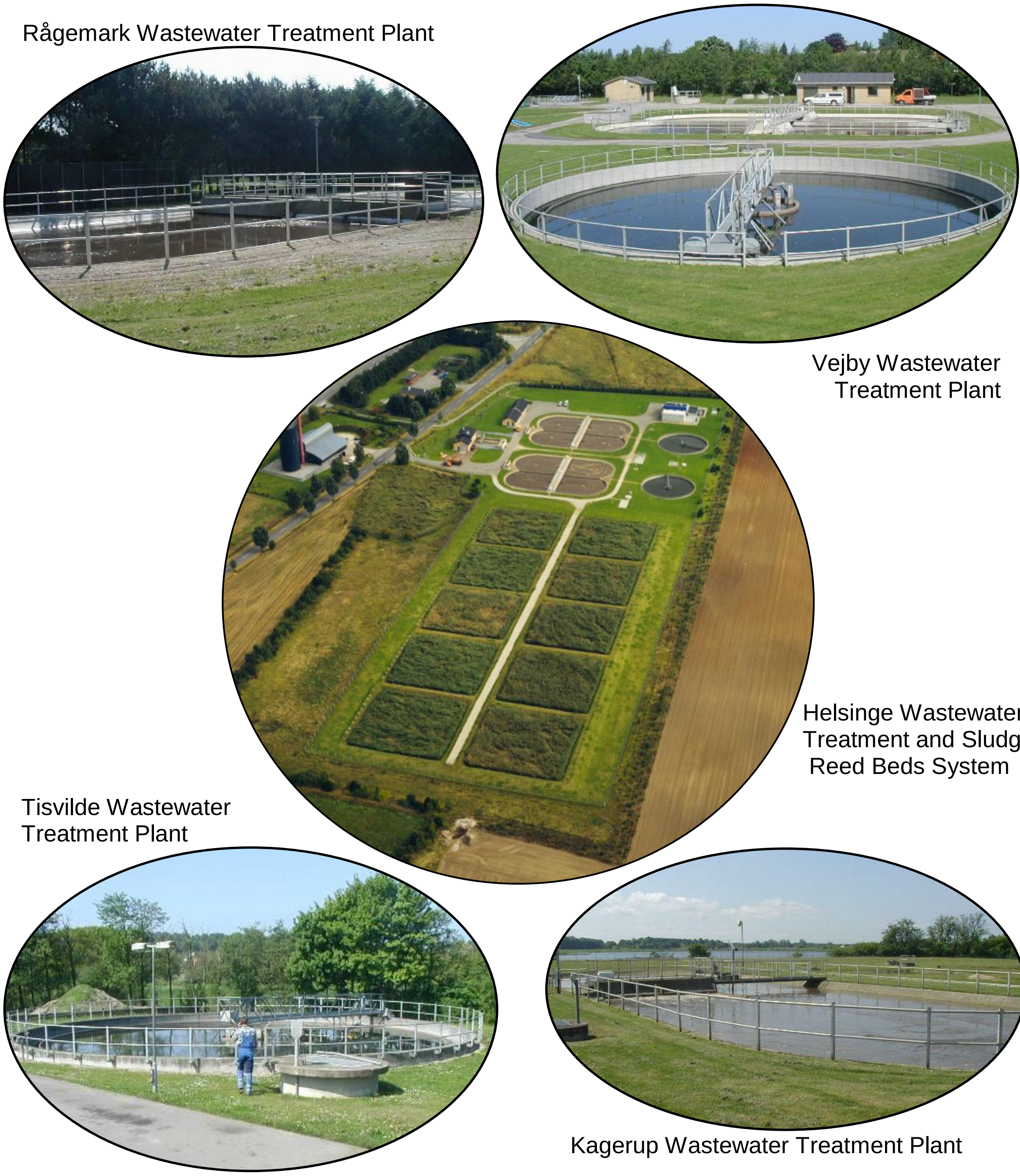

Fig. 1 Wastewater treatment plants and sludge reed bed system in the Helsinge municipality

Table 1 Treatment plants in the municipality of Helsinge

Treatment plant	Dimensions (PE)	Current load (PE)	Treatment degree	Precipitant
Helsinge	27,000	18,500	MBNDKF*	$FeSO_4$
Kagerup	1,700	1,398	MBNKL*	$FeCl_3$
Vejby	2,200	2,170	MBNDKF	Aluminium
Tisvilde	7,500	6,920	MBNDK	Aluminium
Rågemark	4,200	4,200	MB	-

*Lagoons (L) and filters (F) for Postpolishing

The smaller plants treat wastewater and sludge as follows:

Kagerup Wastewater Treatment Plant (Fig. 1)
The plant (Table 1) consists of a bar screen, sand trap with built-in grease trap and an active sludge plant (ring canal). The treatment process uses 41,600 kg ferric chloride annually. (Pix 115). The precipitant is added to the sand trap at a rate of 30-40ml/min./day. The ring canal delivers 2.7m^3 stabilised, residue sludge daily (sludge age > 20 days). The sludge is pumped to a concentration tank (126 m^3), from which approx. 26 m^3 (2.4 % dry solid) is discharged about 22 times a year. All in all, approx. 600 m^3 is transported the 4 km to the Helsinge treatment plant.

Vejby Wastewater Treatment Plant (Fig. 1)
The plant (Table 1) consists of a bar screen, sand trap with built-in grease trap and an active sludge plant (double ring canal) and clarifying tank. The treatment process uses 66,000 kg of the precipitant Pax 14 (aluminium), which is added to the sand trap at a rate of approx. 40 ml/min/day. Daily, 65 m^3 of stabilised residue sludge is removed from the clarifying tank via the return pumping station (sludge age >20 days). The sludge is pumped to a concentration tank (126 m^3), from where c. 36 m^3 (1.3 % dry solid) is taken about 50 times a year. In all, approx. 1,800 m^3 is transported the 10 km to the Helsinge treatment plant.

Tisvilde Wastewater Treatment Plant (Fig. 1)
The plant (Table 1) consists of a bar screen, sand trap with built-in grease trap and an active sludge plant (double ring canal) and clarifying tank. The treatment process uses 99, 000 kg of the precipitant Pax 14 (aluminium), which is added to the sand trap at a rate of approx. 140 ml/min/day. Daily, 72 m^3 of stabilised residue sludge is removed from the clarifying tank via the return pumping station (sludge age >20 days). The sludge is pumped to a concentration tank (140 m^3), from where c. 44 m^3 (2.5 % dry solid) is taken about 115 times a year. In all, approx. 5,000 m^3 is transported the 10 km to the Helsinge treatment plant.

Rågemark Wastewater Treatment Plant (Fig. 1)
The plant (Table 1) consists of a bar screen, sand trap with built-in grease trap and an active sludge plant (single ring canal) and clarifying tank. The treatment process uses no precipitant. Daily, 100 m^3 of stabilised residue sludge is removed from the clarifying tank via the return pumping station (sludge age >20 days). The sludge is pumped to a concentration tank (110 m^3), from where c. 40 m^3 (3 % dry solid) is taken about 33 times a year. In all, approx. 1,300 m^3 is transported the 13 km to the Helsinge treatment plant.

Helsinge Wastewater Treatment Plant (Fig. 1)
The treatment plant is constructed (table 1) with an aerated sand trap and grease trap, two active sludge plants (double ring canals), 2 clarifying tanks and sand filer before discharge. The treatment process uses approx. 180,000 kg $FeSO_4$ annually. The precipitant is added to the inlet of the aerated sand trap and grease trap at a rate of c. 200 ml/min (12 hr./day). In addition to wastewater, the Helsinge treatment plant receives septic sludge (approx. 4,000 m^3) from approx. 1,000 homes. Septic tanks and the sludge tank are emptied once a year in August- September, in all about 500 units, and transported to storage tank no. 2 (180 m^3) and from here during the night to the Helsinge treatment plant intake. The sludge (sludge age > 20 days) from the ring canals

gravitates to a distributor and from there to the clarifying tanks. In the distributor, aerobic active sludge is taken from the ring canals for the sludge mineralisation plant. The sludge is primarily derived from the active sludge plants. In periods where input to the treatment plant is low, sludge input to the sludge plant can be supplemented with sludge from the clarifying tanks. Twice daily, 100-125 m^3 stabilised residue sludge (c. 0.4 – 0.65 % dry solid) is lead to a mixing tank.

Sludge treatment

Sludge from the four smaller treatment plants is transported by tank truck (cap. approx.10 m^3) to storage tank no.1 (156 m^3) at the Helsinge treatment plant, where the anaerobic sludge is stored. During the period 1992 to 1996-1998, the accumulated sludge production was mechanically dewatered in a filter belt press. After dewatering, the sludge was stored in a field stack, to be deposited on agricultural land in August/September each year. In 1996, a sludge mineralisation plant was established at the Helsinge treatment plant, and after a two-year running-in period, an annual treatment capacity of 630 tons dry solid was reached in 1999.

Sludge production from the Helsinge wastewater treatment plant consists of activated sludge directly from the activated sludge plant and activated sludge from final settling tanks. The production (tons dry solids) constitutes approximately 66% of the loading of the sludge reed bed system. The remaining 33% of the sludge production consists of concentrated activated sludge from four smaller wastewater treatment plants (Table 3).

The proportions depend on whether there is sludge in storage tank no. 1. Generally speaking, very little sludge is delivered to the storage tank from the four smaller treatment plants in the period from January-March. In addition, wear and tear on the storage tank's pump results in decreased production and constantly changing proportions in the mix. The two types of sludge are mixed in each delivery (Table 2) before being added to the reed bed system. The sludge from storage tank no. 1 is pumped (c. 20-30 m^3/h) along with discharge (table 2) of sludge from the Helsinge treatment plant to a mixing tank (c. 24 m^3). In the mixing tank, the aerobe sludge from the Helsinge treatment plant is "de-aerated" and mixed with anaerobic sludge from storage tank no. 1. A typical mixture is based on a dry solid content in a ratio of 2:1 on an annual basis. The ratio in the daily input based on dry solid content varies between 1:1 and 2:1.

The sludge is pumped via a mixing tank and a valve building, where the sludge flow and dry solids are registered before being led to the respective basins. The loading regime of the system consists of applications of approximately 130-150 m^3 of sludge (mixed sludge) being applied once or twice daily (Table 2) to the plant's ten basins in relation to individual basins' loading quota and capacity, with the feed concentration being c. 0.5-0.8 % DS.

Table 2: Weekly sludge load. Input periods and times

Day	Input no. 1	Input no. 2
Monday	08.00 – 09.00	13.00 – 14.00
Tuesday	08.00 – 09.00	13.00 – 14.00
Wednesday	08.00 – 09.00	13.00 – 14.00
Thursday	08.00 – 09.00	13.00 – 14.00
Friday	08.00 – 09.00	13.00 – 14.00
Saturday	08.00 – 09.00	13.00 – 14.00
Sunday	–	–

Sludge production

Total sludge production (table 3) has increased during the period from 1997-2005 from approx. 209 tons of dry solid annually to approx. 606 tons of dry solid annually. Sludge production up to 2010 is expected to increase to approx. 700 tons of dry solid, which will necessitate expanding the sludge reed bed system with 2-3 basins.

Table 3. Sludge production (tons dry solid/yr.) from treatment plants in Helsinge municipality

Year	Helsinge	Kagerup	Vejby	Tisvilde	Rågemark	Total
1997	131	8	28	34	8	209
1998	437	9	31	50	31	558
1999	451	9	31	54	29	574
2000	369	13	32	45	23	482
2001	331	11	54	106	26	528
2002	401	15	34	79	22	552
2003	377	12	36	110	37	572
2004	402	12	33	97	21	565
2005	402	14	24	127	40	606

Sludge quality

Throughout the entire period the quality of sludge from the Helsinge wastewater treatment plant loaded into the sludge reed bed system has met the criteria set out in the statutory order on sewage sludge issued by the Ministry of the Environment (Table 4 and Fig. 2) regarding the content of heavy metals and the final disposal of residual sludge on agricultural land (DEPA, 2000). During the ten-year period of operation, sludge from the Helsinge wastewater treatment plant underwent treatment in the reed bed system in the form of draining and evapotranspiration as well as partial mineralisation, reducing the quantity of sludge residue (Nielsen, 2003a,b, 2005).

Table 4. Sludge quality (mixed sludge for sludge mineralisation plant) and Danish standards for deposits on agricultural land (DEPA, 2000)

Parameter	Unit	1997-2006			Danish standards
		Average	Min	Max	
Solids	%	0.79	0.56	1.13	-
Ignition loss	% of ds	52	51	52	-
Total -N	mg/kg ds	43,673	37,100	55,000	-
Ammonium+Ammonia-N	mg/kg ds	6,420	4,600	11,000	-
Nitrate + Nitrate-N	mg/kg ds	256	58	550	-
Total-P	mg/kg ds	28,160	23,000	33,000	-
Ortho-P	mg/kg ds	24,333	22,000	27,000	-
Citrate- and soluble P	% af ds	2.1	1.1	2.7	-
Copper	mg/kg ds	343	270	470	1,000
Chromium	mg/kg ds	17	13	23	100
Zink	mg/kg ds	614	490	860	4,000
Lead	mg/kg ds	34	22	52	120
Lead	mg/kg TP	1,209	730	2,100	10,000
Cadmium	mg/kg ds	0.9	0.5	2.2	0.8
Cadmium	mg/kg TP	32	17	94	100
Mercury	mg/kg ds	0.9	0.1	1.6	0.8
Mercury	mg/kg TP	31	5.7	61	200
Nickel	mg/kg ds	25	14	69	30
Nickel	mg/kg TP	885	460	2,700	2,500
DEHP	mg/kg ds	14.9	5.3	23	50
LAS	mg/kg ds	50	50	51	1,300
NPE	mg/kg ds	2.4	0.7	5	10
PAH	mg/kg ds	1.1	0.4	2	3

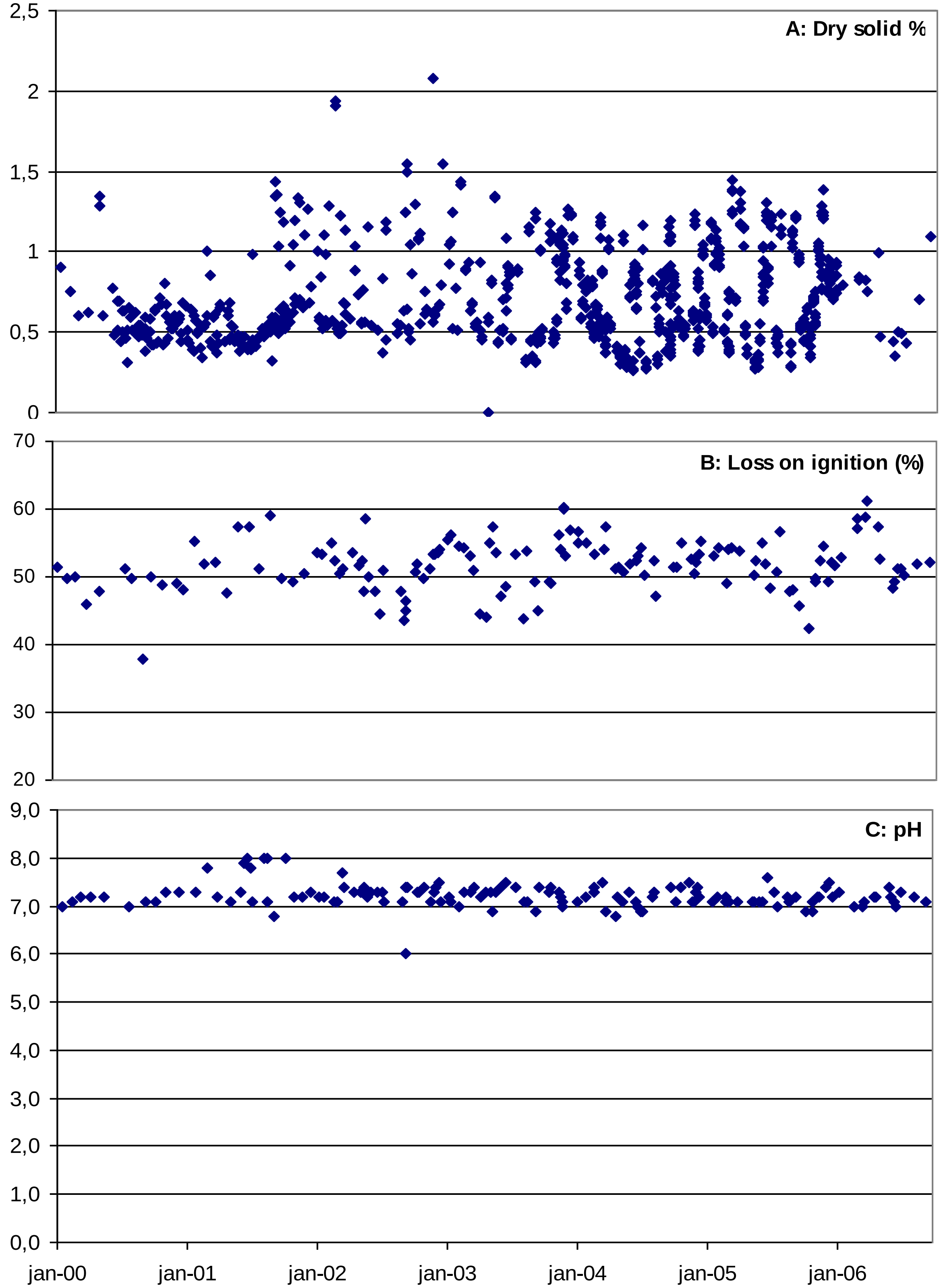

Fig. 2: Sludge quality. Mixed sludge for Sludge Reed Bed System (1997 – 2006). A: dry solids (%). B: Ignition loss (%). C: pH.

HELSINGE SLUDGE REED BED SYSTEM

The Helsinge Sludge Reed Bed System was established and the reeds planted in October 1996 (Fig. 1). The reed bed system has a capacity of 630 TDS per year and consists of 10 basins, each having an area of 1,050 m^2 at the filter surface and a maximum area loading rate of 60 kg DS/m^2/year.

Loading

The annual load rate (tons dry solids) of the Helsinge sludge reed bed system during the period from start of operations and to 2005 has been in the order of 90 % of capacity. From 2000 to 2005, loading has increased by approx. 130 tons dry solids. If this development continues, the plant's capacity of 630 tons dry solids will be reached in a few years time (Fig. 3).

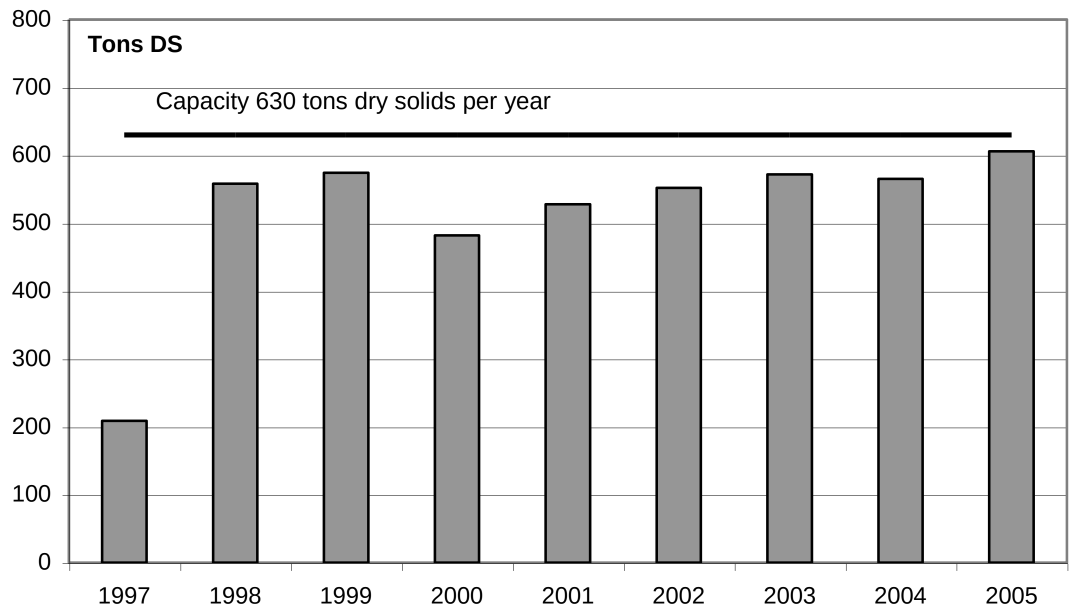

Fig. 3: Helsinge Sludge Reed Bed System. Sludge production and load (tons ds per year)

During commissioning (1996-1998), the quota (the volume of sludge loaded on a basin before the load on the next basin is started) was increased from approx. 200 to 1,000 m^3 (Table 5). The loading period was followed by 10-45 rest days for dewatering and conversion of sludge organic solid (Nielsen 2003a,b, 2005).

From 1999, each basin was subjected to a loading quota of 1,250 m^3 for 5-6 days during each loading period. From 2000, each basin was subjected to a loading quota of 1,500 m^3 over a loading period of approx. 5-7 days. Loading was followed by 45-65 rest days. The quota loading is adjusted by roughly a factor 10 during the 10-year period of operation (Table 5), from approximately 150 m^3 to 1,500 m^3 (Nielsen 2003a,b, 2005).

After commissioning, from 1998 the individual basins were subjected to an average loading rate of 40-50 kg dry solid/m^2/year. Because of the increasing sludge production and emptying of two basins yearly, the area-specific loading rate has increased from approximately 46 kg DS/m^2/year in 2000 to 68-83 kg DS/m^2/year in 2005. Expectations for operations are that the last 2-3 basins are emptied in 2008.

Table 5. Helsinge Sludge reed bed. Quota (m^3) and quota loading rate (kg dry solid/m^2)

Year of operation	Loading days per basin	Rest days per basin	Quota (m^3)	Quota loading rate (kg dry solid/m^2)	Number of basins
1(97)	1-3	10-30	150-400	1-2	10
2 (98)	1-3	10-30	700-1,000	3-6	10
3(99)	3-5	25-45	1,250	6-7	10
4(00)	5-7	45-65	1,500	7-9	10
5(01)	5-7	45-65	1,500	7-9	10
6(02)	5-7	45-65	1,500	7-9	10
7(03)	5-7	45-65	1,500	7-9	10
8(04)	5-7	45-65	1,500	7-9	10
9(05)	5-7	40-50	1,500	7-9	8*
10(06)	5-7	40-50	1,500	7-9	8*

*8 basins in operation and 2 basins inoperative due to emptying

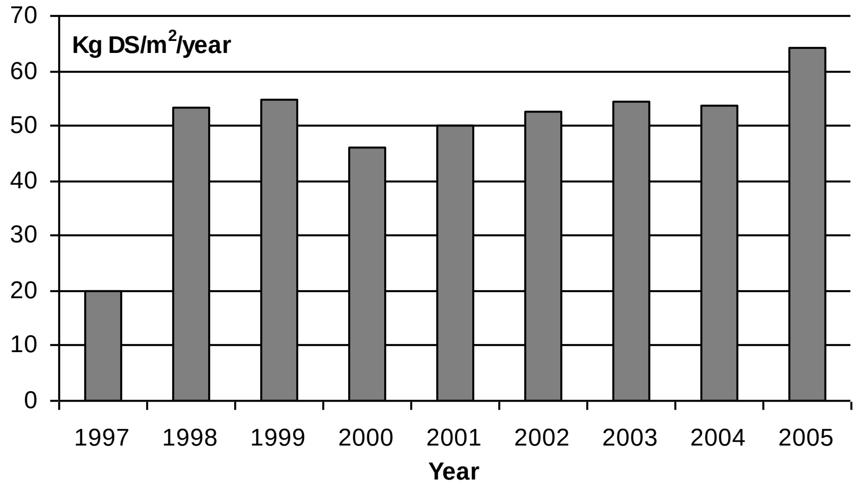

Fig. 4 Helsinge Sludge Reed Bed System – Average area loading rate (kg dry solid/m^2/year)

Since 1998, individual basins, were subjected to an average loading rate of approx. 55 tons dry solid per year after commissioning resulting in an average area-specific loading rate of 55-64 kg dry solids/ m^2/year (Fig. 4). The sludge residue height status in basin 1 in relation to time and area-specific loading rate (kg dry solid/m^2/year) was calculated on the basis of scale pole readings (Nielsen 2003a,b, 2005). The sludge residue height increase from 1998 to 2005 was approx. 1.20 m (basin no. 1), and the total sludge residue height by April 2006 was approximately1.40m (Fig. 5).

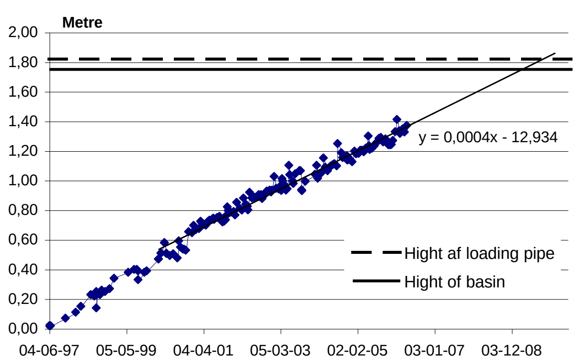

Fig. 5. Helsinge Sludge Reed Bed Systems. Basin no.1. Sludge residue increment

Sludge residue quality

The quality of the sludge residue in the Helsinge sludge reed bed system meets the criteria set out in the statutory order on sewage sludge from the Ministry of the Environment, and the final disposal of the residual sludge will be on agricultural land (DEPA, 2000). The quality of the sludge residue with regard to heavy metals and hazardous organic compounds met the criteria of the statutory order (DEPA, 2000). The analyses were performed prior to emptying the basins. The dry solids content in the sludge residue was up to 35.5%. Nitrogen and Phosphorus contents were on the order of 22,000-28,000 and 30,000 mg/kg dry solid, respectively. The quality of the sludge residue after ten years of biological treatment in the sludge reed bed system met valid statutory order criteria for use on agricultural land (Table 6).

Table 6. Sludge residue quality in relation to operating period (DEPA, 2000)

Basin		5	8	2+7	Danish Standard
Operating period		1996-2005	1996-2005	1996-2006	-
Date		18-08-2005	18-08-2005	26-06-2006	-
Loss on ignition	% ds	46.7	43.8	43-46	-
Dry solids	%	20.4	22.2	18.3 – 35.5	-
Lead	mg/kg ds	44	49	36	120
	mg/kg P	1,400	1,600	1,200	10,000
Cadmium	mg/kg ds	1.4	1.2	1.2	0.8
	mg/kg P	43	38	40	100
Chromium	mg/kg ds	18	19	22	100
Cobber	mg/kg ds	390	390	400	1,000
Mercury	mg/kg ds	0.63	0.62	0.45	0.8
	mg/kg P	20	20	15	200
Nickel	mg/kg ds	18	20	21	30
	mg/kg P	570	620	720	2,500
Zinc	mg/kg ds	590	640	620	4,000
Total Nitrogen	mg/kg ds	25,600	21,900	28,000	-
Total Phosphorus	mg/kg ds	32,000	32,000	30,000	-
Sum NPE	mg/kg ds	1	0.6	0.4	10
Sum af PAH	mg/kg ds	1.7	1.1	1	3
DEHP	mg/kg ds	2.4	1.4	3.4	50
LAS	mg/kg ds	<50	<50	<50	1,300
Oil	mg/kg ds	-	-	30-40	-
Fat	mg/kg ds	-	-	120-220	-
Calcium	mg/kg ds	-	-	25,500	-
Iron	mg/kg ds	-	-	79,000	-

Pathogenic microorganisms

As a general rule, pathogenic bacteria that are excreted and end in an alien environment only live for a short period of time, depending upon various environmental factors and the bacteria's own characteristics. The sludge (approximately 0.5-0.8% DS) loaded into the individual basins contained a large number of bacteria. Salmonella, Enterococci and E. Coli were found in the sludge in the following quantities: 10-300 per 100g (wet weight), 7,000 – 25,0000 CFU/g (wet weight) and 800,000 – 10,000,000 CFU/100g (wet weight), respectively. Analysis of the reduction in pathogens in the sludge residue through a period of 1-4 months (Nielsen 2006) after the last loading from the Helsinge sludge reed bed system (basin no. 8) indicated that the pathogen content was reduced to <2 per 100g (Salmonella), <10 CFU/g (Enterococci) and <200 number/100g (E. Coli). For Enterococci and E. Coli the reduction was approximately log 5 and log 6-7, respectively (Fig. 6).

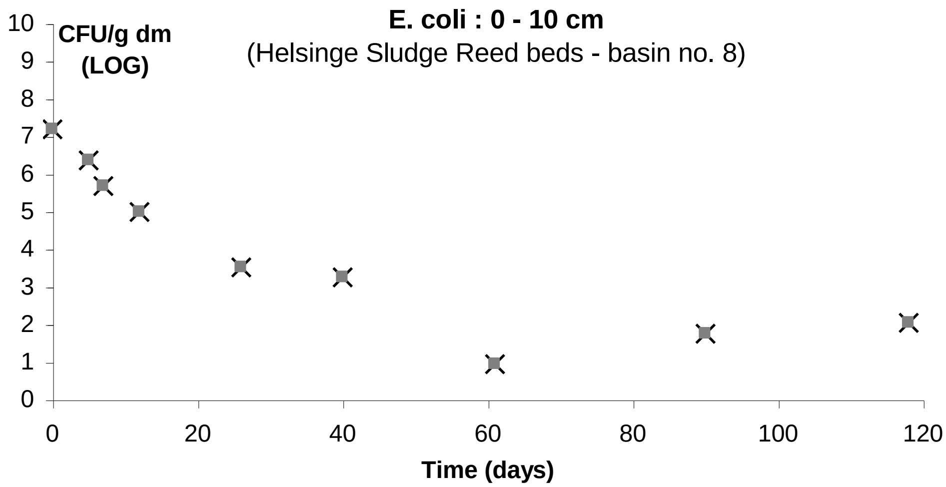

Fig. 6: Quality of sludge residue. Reduction of E. Coli (depth: 0 – 0.10 m) measured in the period from June to October 2004. Helsinge sludge reed beds – basin no. 8

EMTYING

The plan is to empty the Helsinge sludge reed bed system over a 5-year period with 2-3 out of 10 basins selected for emptying per year. The two basins selected for emptying are excluded from the loading plan approximately ½-1 year before emptying, and have a reduced load the first year after emtying. Capacity during the emptying period (5 years) is maintained at 630 tons of dry solids per year despite reduction of the basin number during the emptying period from 10 to 8 (6) basins in operations. Loading of the other basins is therefore increased correspondingly. Emptying commenced according to plan in 2005 (Nielsen, 2003a,b, 2005).

The sludge residue is increased by approx. 250 m^3 per year. The forecast is to ensure that emptying of the basins is commenced in due time so that sludge system operation proceeds in such a way as to prevent overloading of the other basins, and so that the last basins selected for emptying are not overfilled with sludge residue before emptying. The first two basins are emptied so as to ensure that the sludge residue height in the last two basins does not exceed approximately 1.7 m after approximately 10 - 15 years of loading.

The distance between the emptying height (1.5 m) and the crown edge (1.8 m) is regarded as a buffer area included in the forecast to ensure that the capacity of the last two basins is sufficient to prevent sludge overflow from the basins before the last are emptied. The forecast buffer area also provides for an increase in the sludge residue height per added unit of dry solid when increasing the loading of individual basins from approximately 55 to 85 kg dry solid/m^2/year, as system loading during the emptying period applies to only 8 basins. The sludge residue height in individual basins determines which basins are to be emptied first, so that the two basins with the highest sludge residue volume are selected first. The emptying forecast is prepared on the basis of registrations of sludge residue height and accumulated area-specific loading rate (kg dry solid/m^2/year) after commissioning.

Fig. 7: Emptying in 2006 (basin no. 2)

Basins no. 5 and 8 were selected for emptying and were taken out of operation in June 2004. They were emptied in the period from Aug. 25 2005 to Sept. 01 2005. Basins no 2 and 7 were selected for emptying and were taken out of operation April 2006 and emptied in the period from Sept. 22 2005 to Sept. 06 2006 (Fig. 7). From each of the basins approximately 1,000-1,400 tons of sludge residues (Table 7) were removed. The sludge residue was deposited on approx. 158-170 Ha taking into consideration Phosphorus content (Table 7) with max. 90 kg P/Ha for individual areas every third year.

Table 7: Emptying data, Helsinge sludge Reed Bed System

Basin	Emptying yr.	Height, sludge residue (m)	Sludge volume removed (m^3)	Deposit rate (tons ds/Ha)	Deposit area (Ha)
5	2005	C. 1.20 – 1.25	1,070	14	
8	2005	C. 1.00 – 1.10	1,009	13	158
2	2006	C. 1.30 – 1.40	1,315		
7	2006	C. 1.35 – 1.40	1,441	16,4	170

Regeneration of vegetation

Maintaining full capacity during emptying is only possible provided that the basins are re-established after emptying with sufficient regeneration of vegetation, and provided that the loading rate is adapted to vegetation growth. Helsinge has had a satisfactory rate of regeneration after emptying in both 2005 and 2006 (Fig. 8), so that re-planting basins has not been necessary.

Fig. 8: Regeneration 2006 in basin no.2

Approx. 10 months after emptying, basins no. 5 and 8 have fully established regeneration. Loading is at the same level as before emptying, where the quota was 1,500 m^3 in each cycle. Basins no. 2 and 7 have already received the first loads approx. 1-2 months after emptying. Thus it has not been necessary to reduce loading. In the first two years of the emptying period, where 4 basins have been emptied, the Helsinge sludge reed bed system has maintained its capacity of 630 tons dry solid per year.

CONCLUSION

This paper presents experience and know-how from a 19-year period (1988-2006), primarily with references from Denmark. The accumulation of knowledge, guidelines for dimensioning and operations, and descriptions are based on experience from more than 50 sludge reed bed systems, mainly loaded with activated sludge residue. The Sludge Treatment Reed Bed System is a long-term sludge solution, and the systems are built to treat sludge for an average operative period of 10 years. Experience shows that operation is reliable and flexible, with very low operating costs, low energy consumption, no use of chemicals (polymers) for dewatering, an improved working environment and the freeing-up of waste water treatment capacity.

The basins in Helsinge sludge reed bed system have, since 1998, been subjected to an average loading rate of approx. 55 tons dry solid per year, resulting in an average area-specific loading rate of 55-64 kg dry solid/m^2/year. The sludge residue height in relation to time and area-specific loading rate increase from 1998 to 2005 was approximately 1.20 m., or approximately 0.17 m per year. The total sludge residue height by April 2006 was approximately 1.40m. It has been possible to maintain full capacity during emptying because the basins are re-established after emptying with sufficient regeneration of vegetation. It has thus not been necessary to re-plant basins.

Experience shows that good mineralisation of hazardous organic compounds, good reduction of pathogenic microorganisms and a final dry solids content of 30 - 40% can be achieved.
The quality of the sludge residue for heavy metals and hazardous organic compounds met the criteria regarding sludge residue laid down by the statutory order on sewage sludge from the Ministry of the Environment, and the final disposal of residual sludge will be on agricultural land. With respect to heavy metals, hazardous organic compounds and pathogen removal 10 years of treatment make it possible to recycle the biosolids to agriculture as an advanced treated product.

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