PROJECT 96-CTS-4

INVESTIGATION OF HYBRID SYSTEMS FOR ENHANCED NUTRIENT CONTROL

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Freising Treatment Plant, Germany

Facility:	Freising WWTP Germany
Process:	IFAS Linpor CN process Operating in MLE mode
Media:	**Type:** Sponge **Manufacturer:** Linpor
Type Study:	Full-Scale Upgrade
Capacity:	5.3 mgd 20,000 m^3/d
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Introduction

The Freising plant was first upgraded in 1984 as a Linpor C system for BOD removal. Media was installed in the activated sludge tank to enhance carbon removal (Linpor C process). The plant was upgraded and expanded in 1992–93 to increase capacity and include denitrification to meet a standard of 18 mg/L for total nitrogen and 10 mg/L for BOD_5. German regulations require effluent permit compliance to be achieved 80% of the time (4 out of 5 measurements). Nitrogen removal is not required when the influent wastewater temperature is 12°C or colder. The plant receives a combination of municipal and industrial wastewater. It is designed to treat 110,000 population equivalent (40 g BOD_5 per population equivalent). The design BOD_5 and TKN loads are 4,400 kg/d (9,700 lb/d) and 900 kg/d (1,985 lb/d) respectively, and an average flow of 20,000 m^3/d (5.3 mgd). Since 1994, the plant has been treating 100% of the design flow and 90% of the load.

The Linpor CN process, which incorporates both BOD removal and nitrification in the same tank, was used for the upgrade. An anoxic zone was configured at the head of each activated sludge tank. The aerobic zone has a media fill volume fraction of 0.18. The media is 15 mm × 12 mm × 12 mm (0.6 in × 0.47 in × 0.47 in) polyurethane cuboids.

Flows and Waste Strengths

Data for 12 months from July 1994 to July 1995 were provided by the operator (see Table FR-1). This was a period of official and detailed sampling including characterization of the raw influent, primary effluent, and final effluent for nitrogen species. The performance of the Linpor system is shown in Table FR-2.

Table FR-1. Influent Flows and Strengths

Month	Raw Influent					Influent to Linpor System			
	Flow m^3/d	BOD_5 mg/L	COD mg/L	NH4N mg/L	TP mg/L	BOD_5 mg/L	COD mg/L	NH4N mg/L	TKN mg/L
Jul-94	18,513	171	261	23	6.0	187	340	29	38
Aug-94	17,874	203	354	21	6.2	186	209	27	35
Sep-94	18,498	187	367	20	6.7	182	340	24	31
Oct-94	25,341	149	347	25	6.6	102	300	31	40
Nov-94	16,642	159	303	27	6.0	160	270	29	38
Dec-94	19,912	209	432	21	7.6	170	301	30	31
Jan-95	19,301	172	357	25	8.1	167	307	30	32
Feb-95	19,608	302	438	21	7.6	187	301	24	31
Mar-95	20,418	162	345	18	7.6	187	317	29	34
Apr-95	31,353	145	303	19	7.6	188	317	24	31
May-95	23,343	308	601	21	10.4	208	634	24	31
Jun-95	30,646	103	251	17	5.0	104	315	19	35
Average	21,787	189	363	22	7.1	169	329	27	34
Max	31,353	308	601	27	10.4	208	634	31	40
Min	16,642	103	251	17	5.0	102	209	19	31

Table FR-2. Operating Characteristics

Month	Flow	Influent to Linpor System				Linpor Basin Characteristics						Plant Effluent				
	m^3/d	BOD_5 mg/L	COD mg/L	NH4N mg/L	TKN mg/L	MLSS mg/L	MLSS Total (1) mg/L	SVI mL/g	RAS Flow to Inf Flow	MCRT days	Temp C	BOD_5 mg/L	COD mg/L	TSS mg/L	NH4N mg/L	NOxN mg/L
Jul-94	18,513	187	340	29	38	7,000	8,200	50	1	11.4	20.0	4	21	5	0.07	7
Aug-94	17,874	186	209	27	35	7,200	8,380	54	1.1	14.2	17.0	4	20	4	0.40	7.5
Sep-94	18,498	182	340	24	31	6,700	8,360	54	1	11.1	15.7	3	28		0.45	7.2
Oct-94	25,341	102	300	31	40	7,710	9,770	51	0.9	13.3	16.0	3	22	5	0.08	9.4
Nov-94	16,642	160	270	29	38	7,700	8,760	50	1	13.4	15.3	3	18	6	0.08	13.3
Dec-94	19,912	170	301	30	31	7,600	9,850	50	1	11	12.7	3	19	6	0.14	11.6
Jan-95	19,301	167	307	30	32	5,030	10,020	48	1	13.2	12.0	4	27	5	0.13	12.1
Feb-95	19,608	187	301	24	31	5,850	10,550	48	1	11.4	12.7	2	21	6	0.15	10.7
Mar-95	20,418	187	317	29	34	5,800	10,240	47	1	13.2	11.0	2	19	5	0.14	11.6
Apr-95	31,353	188	317	24	31	7,820	9,010	60	0.9	12.4	12.0	4	18	7	0.32	9.4
May-95	23,343	208	634	24	31	8,400	10,220	52	0.9	9	13.0	2	21		0.10	6.7
Jun-95	30,646	104	315	19	35	6,700	8,850	48	0.7	10.4	14.0	2	14		0.26	7.9
Average	21,787	169	329	27	34	6,960	9,350	51	1	12.0	14.3	3	21	5	0.19	9.53
Max	31,353	208	634	31	40	8,400	10,550	60	1	14.2	20.0	4	28	7	0.45	13.30
Min	16,642	102	209	19	31	5,030	8,200	47	1	9.0	11.0	2	14	4	0.07	6.70

(1) Includes suspended solids and biomass in sponge cuboids.

The raw influent includes some contribution from industries. The primary effluent includes recycles from solids handling units — principally from thickening and dewatering.

Description of Facilities

Headworks

The Freising plant has relatively coarse screens compared to other Linpor facilities. The openings in the screens are 20 mm ($^3/_4$ in) wide. Linde, the supplier of the Linpor process, normally recommends fine screens with 5 mm (0.2 inch) openings to avoid excessive accumulation of coarse material in the activated sludge tanks.

Primary Clarifiers

The plant has two rectangular clarifiers with a total surface area of 600 m^2 (6,460 ft^2) and a sidewater depth of 2.25 m (7.4 feet). Normally, it operates with only one of the two clarifiers because of low carbon to nitrogen ratio. It switches operation from one clarifier to the other every 12 hours in summer and every 24 hours in winter. The primaries are alternated to comply with local regulatory requirements that prevent equipment from being taken out of service indefinitely. Therefore, the clarifiers are operated at an overflow rate of 73 $m^3/m^2/d$ (1,800 gpd/sf). The purpose is to keep a high organic load to the reactors to enhance denitrification rates.

Recycle from the sludge thickening and dewatering operations are added to the primary effluent.

Activated Sludge Tanks

The plant has three activated sludge basins with a total volume of 6,230 m^3 (220,000 ft^3). Of this, approximately 20% is anoxic. The volume in each basin is as follows:

- ***Basin (Tank) 1:*** Total Volume = 1,640 m^3,
  Anoxic Volume = 170 – 340 m^3, Aerobic Volume = 1,300 – 1,470 m^3
- ***Basin (Tank) 2:*** Total Volume = 1,640 m^3,
  Anoxic Volume = 170 – 340 m^3, Aerobic Volume = 1,300 – 1,470 m^3
- ***Basin (Tank) 3:*** Total Volume = 2,950 m^3,
  Anoxic Volume = 300 – 600 m^3, Aerobic Volume = 2,350 – 2,650 m^3

The anoxic volume can be varied. Figure FR-1 shows a schematic of the Linpor CN system.

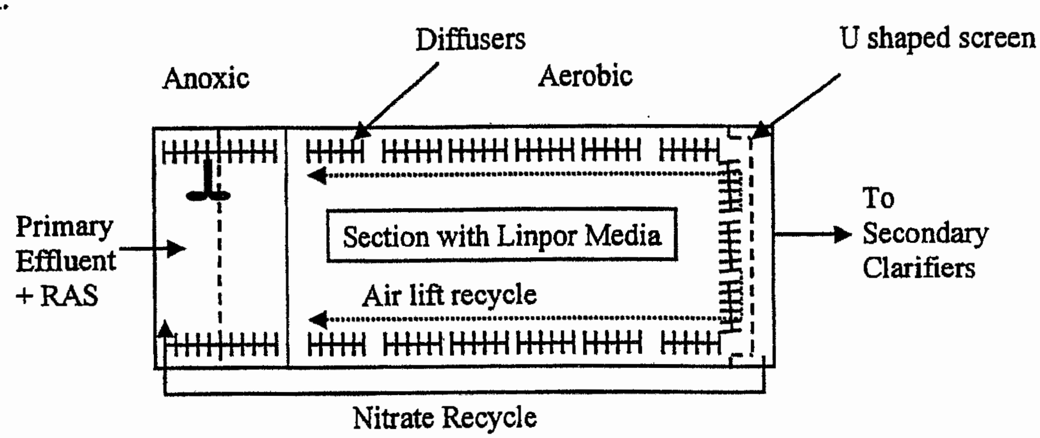

Figure FR-1. Schematic of One Activated Sludge Basin with Media

The system is designed for an HRT of 6 hours and for treating an average primary effluent BOD_5 of 170 mg/L, a biodegradable COD of 300 mg/L, and a TKN of 34 mg/L. This wastewater is 50% stronger than primary effluent in a typical municipal wastewater treatment plant in the United States (115 to 120 mg/L of BOD_5). Therefore, in comparison to a typical municipal wastewater treatment plant with a BOD_5 of 120 mg/L, the HRT is equivalent to

4 hours (6 hours / strength factor of 1.5) for operation at a desired F/M ratio and MLSS. The aerobic HRT is 80% of this value.

At present, the plant is operated at a RAS flow rate of 110% (see Table FR-2 for 1994–95 data). The activated sludge basins have a nitrate recycle. The plant operates with nitrate recycle rates of 100 to 140% of the present flow.

The activated sludge basins have ceramic diffuser pipes for fine-bubble aeration. Other plants typically have membrane diffusers. The diffuser grids are mounted on both sides of the basin to create a double spiral roll. In some plants, the bottom of the tank is shaped as a hump (mound) at the center to enhance the double spiral roll and to prevent settling of sponges (Figure FR-2) in the section of the tank without diffusers. Full floor covering is not used except in Linpor N systems in which the system is designed for separate-stage nitrification in a tank downstream of the secondary clarifiers. With these facilities, all the biomass is in biofilms — there is no RAS or MLSS in the Linpor N systems.

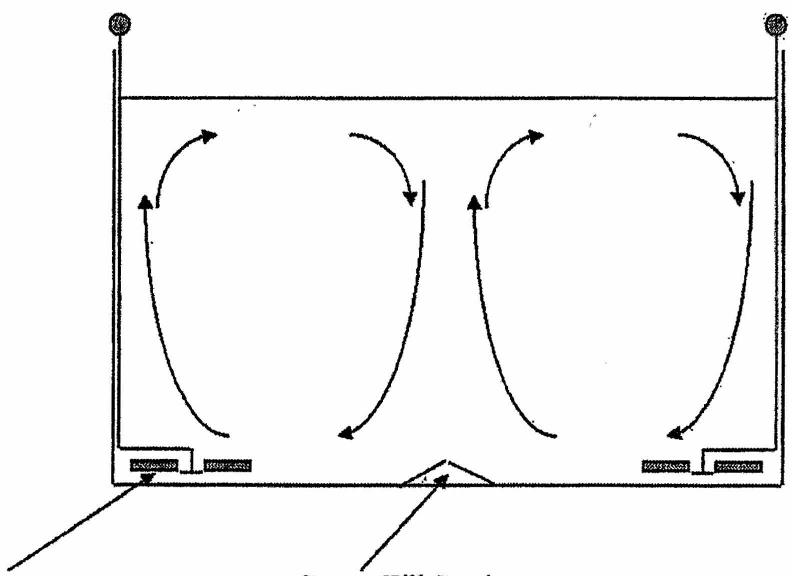

Figure FR-2. Cross-Section of Tank with Media (Double Roll Pattern of Diffusers)

The Linpor media section has an upstream screen just downstream of the anoxic zone. It has a downstream screen before the tank effluent weir. Each section has two air-lift pumps for recirculating the media. There are two nitrate recycle pumps per tank installed downstream of the second screen. A layout of the tank is shown in Figure FR-1. The effluent screen is shaped as shown in the figure (as a fat, U-shaped screen). Linpor favors the U-shaped screen because it ensures that water would continue to flow through the tank even if the aeration system failed (power failure) and the sponges accumulated against the base of the "U." A bank of ceramic pipe diffusers is installed immediately in front of the screen. The U-shape can allow all the sponges to jam up against the base of the U and still allow the top of the U to be free of sponges. The worst-case scenario could occur in the event of a power failure that disrupted the aeration system and the air lifts, and resulted in all the sponge media flowing to the screen.

The media used are 15 mm × 12 mm × 12 mm cuboids. The material is open pore polyurethane with a nominal pore diameter of 0.6 to 0.8 mm. The media has a specific weight of 45 kg/m^3. The media was supplied with a guaranteed wear rate not to exceed 3% per year over a 10-year period. Between 1993 and 1998, the wear rate has been less than 1% per year.

At present, the concentration of biofilm carrier particles is 18%. This is less than the design quantity of 22% because the plant has been able to operate satisfactorily with the lower quantity of media. The rest of the media is kept in storage.

The system is operated at DO levels of 2.5 mg/L to 2.8 mg/L in the Linpor section. This is required to assure complete mixing and full nitrification. The corresponding air-flow rate is 400,000 Nm^3/d (10,000 scfm).

Secondary Clarifiers

The plant has two circular secondary clarifiers. The old clarifier has a diameter of 42 m, but with an outdated design. The sidewater depth is only 1.7 m (5.6 ft). The depth at the center is 7 m (23 ft). It has a bottom-rake system. The new clarifier, which was built as part of the expansion, had to be located 200 meters away due to space constraints. It has a diameter of 30 m (98 ft) and depth of 3.4 m (11.1 ft). It has a flat bottom and a suction-type sludge withdrawal.

The overflow rate with both clarifiers in service is 10.75 m^3/m^2/d (265 gpd/sf), which is fairly low. However, the overflow rate has to be evaluated in terms of the shallow sidewater depth of the larger secondary clarifier.

Performance

The system is designed to handle the regular municipal loads and periodic peak loads from dairy industries. One reason for installing the media was to sustain good nitrification while treating wastewater with high peak loads at a relatively short HRT, considering the strength of the wastewater.

The system has been operated at fairly high MLSS levels (7,000 mg/L; see Table FR-2). This is possible because of the low SVI (51 mL/g, Table FR-2) and low secondary clarifier overflow rates (265 gpd/sf). As a result, the plant is able to maintain a total mixed liquor MCRT of 12 days, of which 9.6 days are aerobic. The operating liquid temperature varies between 11°C and 20°C as a monthly average.

The nitrifiers present in the mixed liquor at an aerobic mixed liquor MCRT of 9.6 days, along with the nitrifiers in the biofilm on the media, combine to give the system excellent nitrification capabilities over the range of flows and loads it experiences. No data are available to separately determine nitrification rates in the biofilm and the mixed liquor. The average effluent ammonium-N was less than 0.2 mg/L (see Table FR-2).

The plant was able to achieve good denitrification. The average effluent NOxN was 9.6 mg/L. The effluent total nitrogen averaged less than 12 mg/L. Nitrogen removal averaged 65% in terms of the primary effluent TKN. The average total nitrogen was well below the limit of 16 mg/L.

The plant achieved excellent effluent quality with respect to BOD_5 (average of 3 mg/L), COD (average less than 25 mg/L) and TSS (average of 5 mg/L).

It is possible that the combination of the anoxic zone and rapid stabilization of BOD in the aerobic zone, using a combination of biofilm and MLSS, contribute to low SVIs, which allow the plant to operate at high MLSS. As a result, the mixed liquor MCRT is higher than was expected at the time of the design. Once this was observed, additional media was not added to increase the fill volume fraction from 0.18 to the design fill fraction of 0.22. The operators found that they could maintain performance with a fill volume fraction of 0.18. Regarding the method of adding sponge cuboids to the tank, it should be noted that the cuboids have to be added gradually over time. Initially, the cuboids are very light (45 g/L) and float on the surface. It can take a few days to two weeks to wet the cuboids floating on top of the aerobic section and to allow the cuboids to accumulate enough growth for them to submerge and roll with the liquid. The downstream screen extends above the water level so that the sponges are retained, but during this period of time, wind can lift sponges from the surface of the tank.

The plant had brief periods when some foam appeared in the tanks. The foam did not spread over the entire surface of the tanks. The foam went away without the operator taking any special action.

The operator has not reported any need to clean the tanks and screens over the first three years of operation after the upgrade and has not added replacement media over this period. This is because the wear rate is averaging less than 1% per year. Media is cleaned with a media squeezing pump on an as-needed basis, which can vary from one month to several months between consecutive cleanings. The intervals can be even longer because the biofilm on the media can reach equilibrium between growth and sloughing rates. The sloughing is due to the rubbing of sponges in the tanks, some squeezing action as the sponges move through the air lift, and from collision against the sides of walls and screens.

The operator is very satisfied with the plant. The screws, air lifts, and sponge cleaning pumps are "basic" technology (as opposed to sophisticated technology) and are extremely reliable.

Information regarding the cost of the upgrade relating just to the sponge media was not available. The 1993 upgrade was an expansion of the facility, which included new tanks, a clarifier, incorporation of anoxic zones, nitrate recycles, media in new tanks, etc. The cost of media and screens are discussed in Chapter 4.