Fine screening system – the more intelligent primary clarifier

Development and integration of innovative sewage treatment plant technologies for the transformation process towards the technology turnaround

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Abstract:

In the discussion about limited resources and energy saving in sewage treatment plants innovative sewage treatment methods are increasingly becoming a focal point. In Germany, there are about 1,200 sewage treatment plants which are designed for 10,000 to 50,000 PE, about one third of them have a sludge digester. Thus, there is a potential of about 800 sewage treatment plants that remains for a change from aerobic sludge stabilisation to processes with anaerobic sludge stabilisation. Until some years ago sludge digestion was found almost exclusively on very large sewage treatment plants (design size 50,000 PE or larger). For sewage treatment plants of a design size smaller than 20,000 PE aerobic sludge stabilisation was much more cost-effective in terms of economic efficiency. Due to rising prices for electricity and heat and the ever increasing costs for sludge disposal sludge digestion is becoming interesting even for sewage treatment plants from design size 10,000 PE on [1].

Keywords:
Aerobic sludge stabilisation, anaerobic sludge stabilisation, preliminary settling tank, fine screening, aeration energy savings, biogas production, load reduction in aeration tank, energy savings

1. GENERAL

For the process changeover from aerobic to anaerobic sludge stabilisation fine screening systems represent a highly interesting alternative to primary settling tanks as fine screening achieves better removal rates than a conventional primary settling tank but on a much smaller footprint and with significantly lower investment costs.

To reduce COD, oxygen is introduced in the biological treatment stage of the wastewater treatment plant to reduce the carbon compounds. This process consumes a considerable amount of aeration energy and therefore causes electricity costs. In case of a plant that is designed for aerobic sludge stabilisation and a capacity of 15,000 PE the annual consumption of electrical energy is approx. 470,000 kWh if the plant is operated 24 hours a day. Assuming a price of 0.18 Cent per kWh the resulting annual fixed costs amount to approx. 85,000 Euro. Changeover from aerobic to anaerobic sludge stabilisation reduces aeration costs by 20-25%. The reduction is achieved through removal of the carbon upstream of the biological treatment stage of the wastewater treatment plant, e.g. by building a preliminary settling tank or installing an intelligent HUBER fine screening system. Fig. 1 shows the development of electricity prices over the past 17 years. It is obvious that there has been a clear trend towards rising energy costs and further increasing energy costs must most probably be anticipated for the future [1].

The research project E-Klär (BMBF FKZ 02WER1319F) focuses among other issues on "Increase gas yield through solids input". In cooperation with the research institution ISA (university of Aachen) and the water authority Ruhrverband processes for the removal of pollution loads in wastewater flows are tested on an industrial scale and analysed on a scientific level. HUBER SE in Berching supplies the mechanical equipment that is required to carry out the tests.

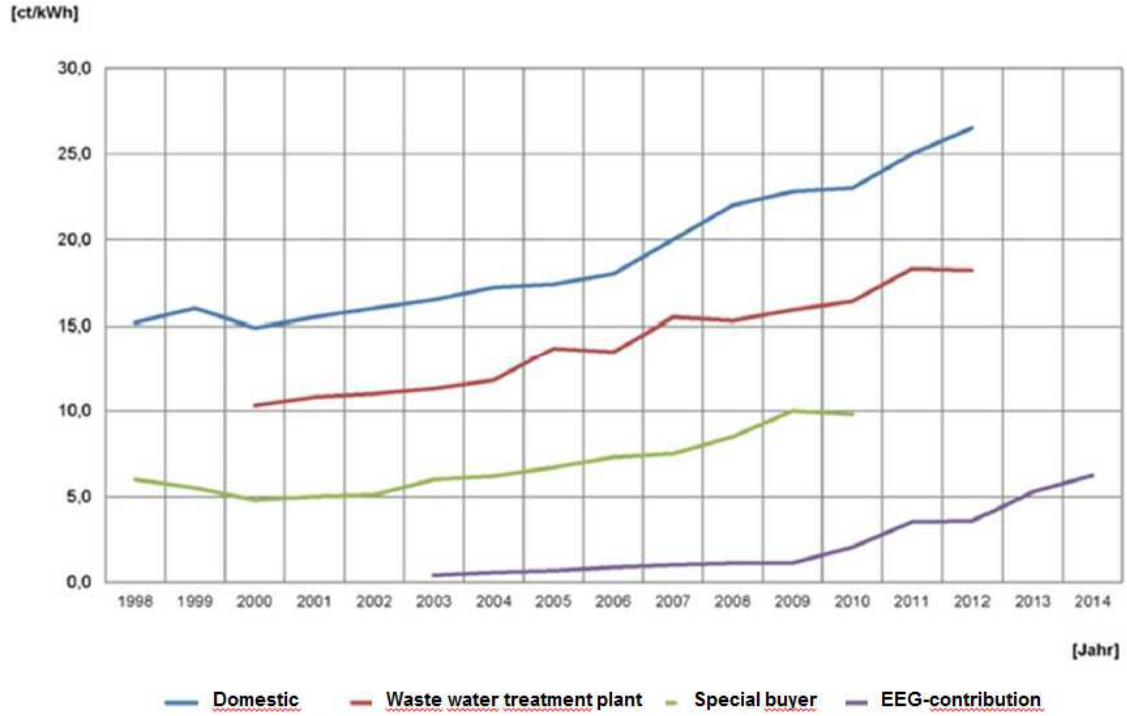

Fig. 1: Development of electricity prices from 1998 to 2014 [1]

The project was initiated in 2014, its central element are the 68 municipal sewage treatment plants operated by the Ruhrverband. These are plants of all sizes and cover a wide spectrum of different processes for sewage treatment. On many of them, whether bigger or smaller, block heat and power stations are installed to provide for the energetic use of the biogas that is generated by the anaerobic sludge stabilisation process. On most of these sewage treatment plants the electric and thermal energy is mainly used directly on site. The start of the project was in early 2015, project duration is 3 years.

2. RESULTS ACHIEVED WITH THE PILOT PLANT

The analysis of the results from a six months test operation of a pilot plant on a sewage treatment plant in Bavaria proved that a fine screening system can reliably serve as replacement for a conventional preliminary settling tank.

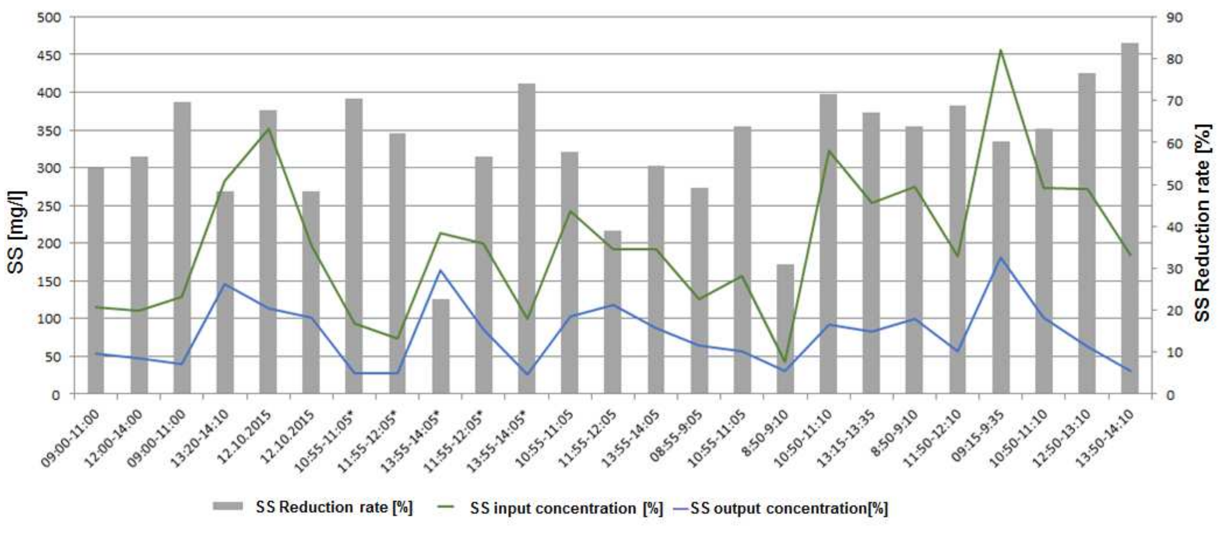

Fig. 2: AFS reduction rates achieved in a long-term test on a sewage treatment plant from September to November 2015 [2]

With the use of an intelligent mechanical fine screen reduction rates of 34-41% for COD and 53-60% for AFS were achieved with average COD inlet concentrations of 440 mg/l and 300 mg/l AFS, as shown in fig. 2-3 [2].

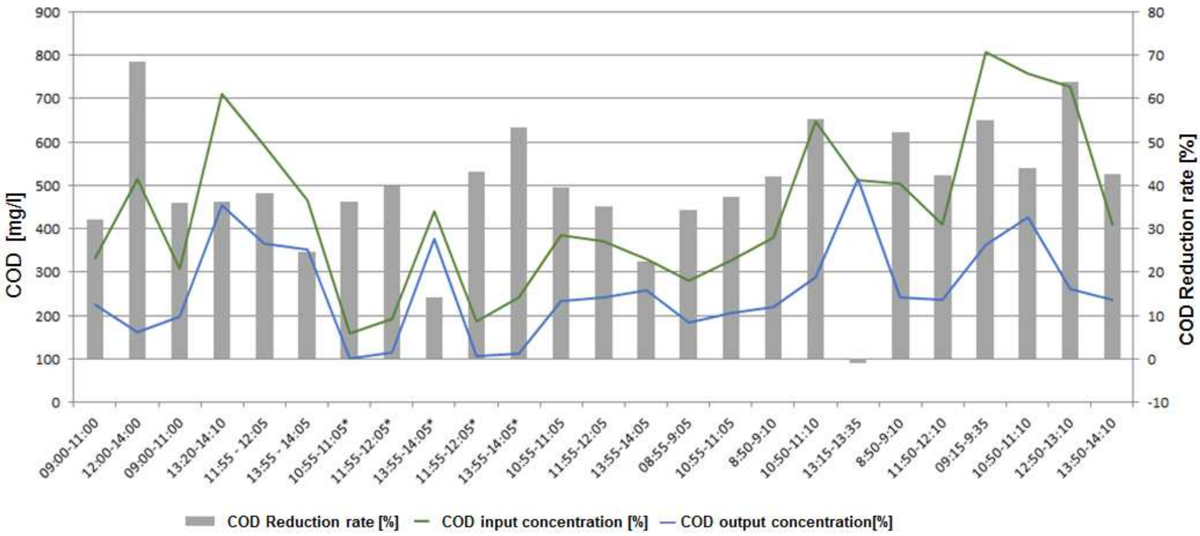

Fig. 3: COD reduction rates achieved in a long-term test on a sewage treatment plant from September to November 2015 [2]

Table 1 shows the separation efficiencies achieved compared to the standard design values for preliminary settling tanks according to ATV-DWVK A 131 [3]. With the use of a fine screening system a separation efficiency could be achieved that was by 9-16% higher for COD and 3-10% higher for AFS than that of a preliminary settling tank [2].

Table 1: Separation efficiencies achieved with a fine screening system and standard design criteria according to ATV A 131 (0.5-1h) [2; 3]

Parameter	ATV A 131 value [g/(PE*d)]	Load [kg/d]	Concentration [mg/l]	Separation with standard plant [%]	Separation with fine screen [%]
BOD5	45	675	277	25	34 - 41
COD	90	1,350	555	25	34 - 41
TS	35	525	216	50	53 - 60
TKN	10	149	61	10	15 - 17
P	1.5	24	10	12	12 - 14

3. AERATION ENERGY SAVINGS THROUGH LOAD REDUCTION IN THE BIO-SYSTEM

The diagram in fig. 4 shows the savings in aeration costs through COD load reduction in the bio-system related to population equivalent. As calculation basis a wastewater COD load of 120 g per PE x day and a COD reduction of 25% for the preliminary settling tank (0.5-1 h residence time) were assumed. The measured COD reduction of 34% / 41% was used in the calculation for the fine screen as intelligent preliminary settling tank. With a size 15,000 PE sewage treatment plant for example the use of a preliminary settling tank results in savings of approx. 20,000 € whereas approx 30,000 € / 35.000 € can be saved with the use of a fine screening system. [1; 3].

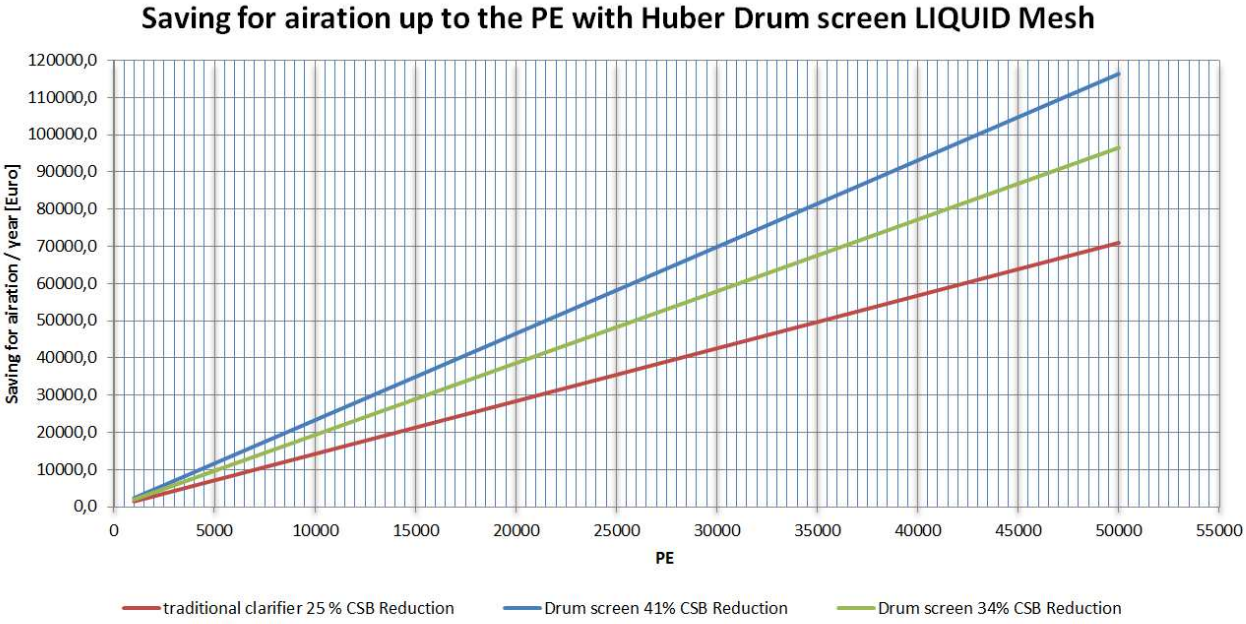

Fig. 4: Comparison of the saving potential of preliminary settling tanks and fine screens on the basis of the potential COD reduction rates of the systems [2]

With the use of preliminary settling tank the specific electricity costs for the aeration energy are in total reduced from 473,040 kWh/a or 31.5 kWh/(PE*a) of aerobic stabilised plants to 354,780 kWh or 23.65 kWh/(PE*a) of plants with anaerobic sludge stabilisation. With the use of a fine screening system the specific electricity costs can be reduced to 20.81 kWh/(PE*a). These figures are equivalent to electricity cost savings of 25% with a preliminary settling tank and 35% with the use of a fine screening system. Figure 2 shows an overview of the savings in a table [2].

Table 2: comparison – consumption and savings on STPs with aerobic or anaerobic sludge stabilisation and with the use of a preliminary settling tank (PST) or fine screening system [3]

	Aerobic sludge stabilisation	**Anaerobic sludge stabilisation**	
		25% COD reduction PST (0.5-1h)	34% COD reduction fine screen
Consumption, aeration [kWh/a]	473,040	354,780	312,206
Consumption, aeration [kWh/(PE*a]	31.54	23.65	20.81
Savings, aeration [kWh/a]	0	118,260	160,834
Savings, aeration with 0.18 Cent/kWh	0	21,287 €	28,950 €
Savings, aeration [Euro/[PE*a]	0	1.42 €	1.93 €
Savings, aeration [kWh/(PE*a)]	0	7.88	10.72

The sludge removed from the system can be predewatered to approx. 3-4% with a *HUBER Wash Press WAP® liquid*. The use of polymer is not necessarily required.

The daily amount of surplus sludge that is generated on a 15,000 PE plant is approx. 335 kg with 3% DS content. If the DS content is increased to 10% in a sludge thickening system the sludge volume can be reduced to 100 kg/day, i.e. 36.5 t sludge a year. These 36.5 t sludge can be introduced to the digestion process on a bigger sewage treatment plant and hold a considerable energy potential [3].

4. CALCULATION OF THE ENERGY POTENTIAL THROUGH LOAD REDUCTION IN THE BIO-SYSTEM

The annual amount of COD according to ATV A 131 is calculated as follows [3]:

120 g COD/PE*day = 43.8 kg COD/PE*year (15,000 PE plant size)

Reduction with 25% COD elimination (0.5-1h residence time): 10.95 kgCOD/PE*year

10.95 kgCOD/PE*year * 10kWh/Nm3methane * 0.35 Nm3methane/kgCOD
= **38.33 kWh/PE*year (energy potential)**

With an electrical efficiency of a block heat and power plant of approx. 41% the electrical energy potential is calculated as follows:

0.41*38.33 kWh/PE*year = **15.72 kWh electrical/PE*year**

With a sludge volume of 36.5 t the electrical power yield resulting from sludge utilisation (digestion) on a size 15,000 PE plant is 235,800 kWh/a. When calculating with 18 Cent/kWh this power yield is equivalent to savings for on-site usage of 42,444 Euro/year.
Taking into account the German renewable energy surcharge ("EEG surcharge") of presently 5.63 Cent/kWh, another 13,276 Euro add to this amount [5].

A size 15,000 PE plant with retrofitted preliminary settling tank can thus save approximately 21,287 Euro for aeration energy on the one hand, and on the other hand produce electric power at the value of to 55,720 Euro (including EEG surcharge) [2].
A fine screening system can reduce COD by 34%, resulting in an electric power production at the value of 75,746 Euro. This is equivalent to an additional surplus of approx. 20,000 Euro compared to a conventional preliminary clarifier. In table 3 a COD reduction of at least 34% is assumed. As COD reduction rates of the fine screening system can vary between 34% and 41%, electricity savings may be approx. 7% higher through on-site usage [2].

Table 3: Comparison of the process variants as to savings through on-site power usage through gasification and power generation in a block heat and power plant [2; 3; 5].

	Electric energy potential [kWh/(PE*a)]	Electric energy potential [kWh/a]	Savings through on-site usage with 18 Cent/kWh [€/a]	Savings through on-site usage incl. 5.63 Cent/kWh from EEG surcharge [€/a]	Total savings incl. EEG surcharge [€/a]	Savings through on-site usage without EEG surcharge [€/(PE*a)]	Savings through on-site usage incl. EEG surcharge [€/(PE*a)]
PST with 25% COD reduction (0.5-1h)	15.72	235,800	42,444 €	13,276 €	55,720 €	2.83 €	3.71 €
Fine screen with 34% COD reduction	21.37	320,550	57,699 €	18,047 €	75,746 €	3.85 €	5.05 €

Table 4 shows that a total of 77,000 Euro/a (aeration energy + power generation) can be saved per year with the use of a conventional preliminary settling tank. This is equivalent to a specific saving of 5.13 Euro/(PE*year) including EEG surcharge.
With the use of a fine screening system, taking into account the savings of aeration energy of 28,950, the resulting total savings (including EEG surcharge) amount to 104,696 Euro/year (aeration energy + power generation) or approx. 7 Euro/(PE*year). Compared to a preliminary settling tank this is an additional surplus of 27,696 Euro of total savings. The resulting additional surplus that can be yielded through power generation and aeration energy savings with the use of a fine screening system instead of a preliminary settling tank is thus 1.85 Euro/(PE*a] [2].

Table 4: Total savings of preliminary settling tank and fine screening system through aeration energy savings and self-generated energy [2]

	Anaerobic	
	25% red. PST [€/year]	34% red. fine screen [€/year]
Self-generated power including EEG surcharge	55,720 €	75,746 €
Aeration energy savings	21,287 €	28,950 €
Total savings	77,007 €	104,696 €
Difference	27,689 €	
Additional surplus through fine screening related to 15,000 PE	1.85 €	

5. COMPOSITION OF THE FINE SCREENINGS FOR DIGESTION

The biogas generated from the screenings that have been separated and fed into the digester is composed of 63 vol% methane content and 37 vol% carbon dioxide, these values confirm the values known from literature [6]. The loss on ignition of the screenings is 88-91%, this is equivalent to the values known from literature [6]. Table 5 shows the results from a fermentation test that was carried out at the Technical University Amberg Weiden over 21 days at mesophilic temperatures.

Table 5: Properties of the fine screenings from a HUBER Drum Screen used in fermentation tests

Properties of the screenings used for fermentation tests at TU Amberg-Weiden	
Dry residue DR	5.4 %
Loss on ignition	89.44 %
Organic dry substance oDR	4.83 %
Seeding sludge	350 ml
Initial sample weight	25.62 g

The results of the fermentation tests carried out with screenings from a fine screening system are summarized in fig. 5, they are comparable to the values known from literature for gas generation from biomass [2].

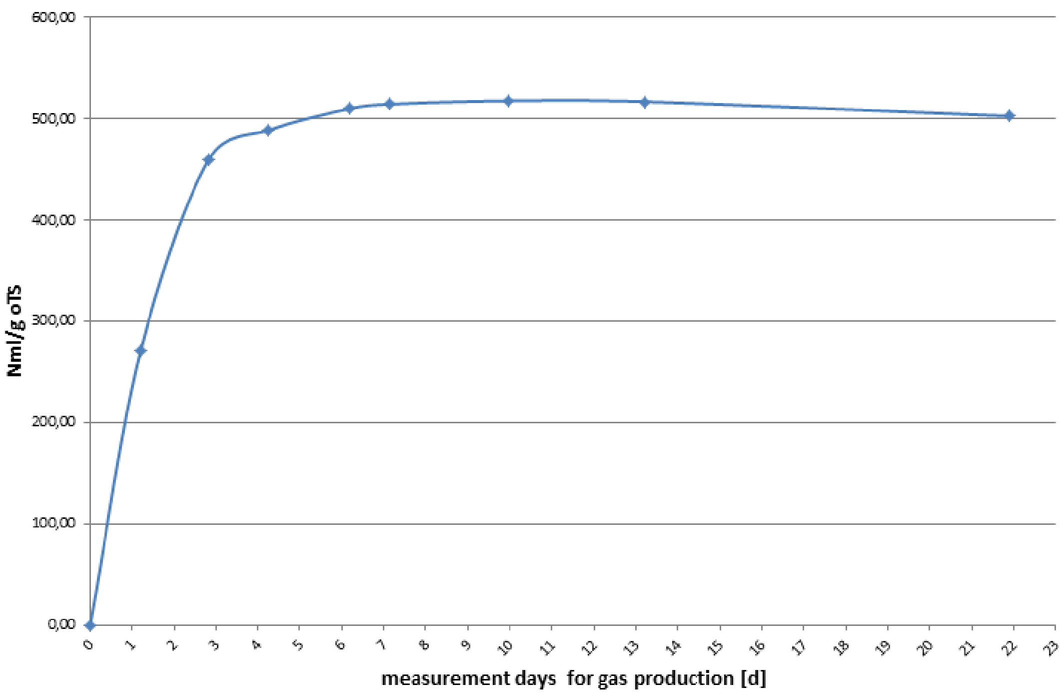

Fig. 5: Specific biogas yield from screenings generated by a HUBER Drum Screen

6. ECONOMIC EFFICIENCY OF PRELIMINARY SETTLING TANK / FINE SCREENING SYSTEM

To be able to compare the costs for a preliminary settling tank and fine screening system, a cost comparison according to the guidelines of the comparative cost method (guidelines for carrying out dynamic cost comparison calculations / German Working Group on Water Issues of the Federal States and the Federal Government LAWA) of DWA is presented here.

The calculation of the cash values of project costs over a period of 30 years is presented to show that the use of a fine screening system is not only profitable related to separation efficiency and increased biogas yield but is also advantageous in terms of the project costs during the entire calculation period.

The economic efficiency calculation compares a fine screening system including thickening press and a conventional preliminary settling tank with scraper installation.

LAWA calculates the calculated values, cash values of projects costs, for the preliminary settling tank with different interest rates. The cash value of project costs indicates the costs the plant operator would incur over the entire depreciation period of 30 years [7].

The depreciation period for structural engineering facilities in the field of wastewater treatment is defined with 30 years. In addition, reinvestment costs for mechanical equipment become due after 15 years. As calculation factors the discount factors for single payments (German "DFAKE") (i;n) were taken from the guidelines of the comparative cost method [7].

The calculation focuses on interest rates between 2.0 and 5.0 percent. The calculated cash values of project costs are then compared with the calculated values for fine screening [7].

The interest rates i = 3% are considered to compare both process variants. Details about the calculation factors and calculation bases can be found in the DWA guidelines for carrying out dynamic cost comparison calculations [7].

The cash value of project costs for the fine screening system relates to an annual interest rate of 3%. Reinvestment costs for mechanical parts become necessary every ten years. Such mechanical parts are gearings, mesh material, perforated plates, etc. After 15 years the pumps and motors of the machines were replaced (pumps, drive motors of wash press and fine screen). The cost comparison calculation delivers the following results [7]:

With the use of a fine screening system (443.000 Euro cash value of project costs) for load reduction in the bio-system in a plant size 15,000 PE about 19% costs can be saved over the entire calculation period compared to a conventional preliminary settling tank (543,000 Euro cash value of project costs.) This means that the profitability of the fine screening system variant is about one fifth higher than that of a conventional preliminary settling tank [7].

The a.m. calculated results refer to an interest rate of 3% and describe only one concrete example of a calculation case. Fig. 6 presents the cash values of project costs for different interest rates and the calculation results:

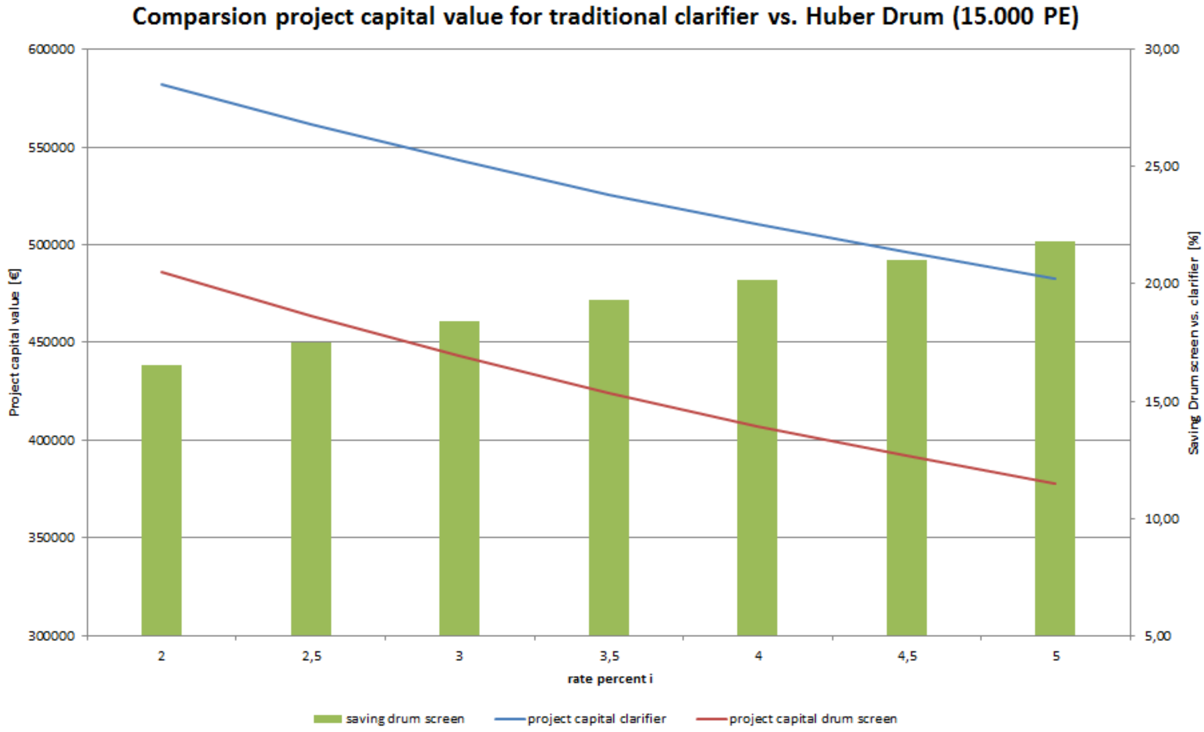

Fig. 6: Comparison of the cash value of project costs of a fine screening system and a conventional preliminary settling tank for a size 15,000 PE plant [7]

Table 6 shows that, related to 15,000 PE, costs are reduced by a total of 11,000 Euro annually with the use of a fine screening system instead of a conventional preliminary settling tank. The resulting additional yield of self-generated power compared to a preliminary settling tank is 1.34 Euro/(PE*a) with a fine screening system. This is equivalent to an additional yield of approx. 20,100 Euro/year [7].

Table 6: Cost/yield comparison of a fine screening system and a conventional preliminary settling tank for a size 15,000 PE plant [7]

	Preliminary settling tank	**Fine screening system**
Biogas yield for power generation and on-site usage	55,720 €/a	75,746 €/a
Population equivalent	15,000 PE	15,000 PE
Specific biogas yield	**3.71 €/PE*a**	**5.05 €/PE*a**
Project costs (LAWA)	18,100 €/a	14,700 €/a
Population equivalent	15,000	15,000
Specific investment costs	**1.20 €/PE*a**	**0.98 €/PE*a**
Aeration costs (24 h/day)	63,860 Euro/a	56,197 Euro/a
Population equivalent	15,000 PE	15,000 PE
Specific operational costs	**4.26 €/PE*a**	**3.75 €/a**
Costs for preliminary settling tank	**5.46 €/PE*a**	
Costs for fine screening system	**4.73 €/PE*a**	
Reduced costs for fine screening system	**0.73 €/PE*a**	

7. MACHINE MODEL SELECTED AS INTELLIGENT PRELIMINARY TREATMENT SYSTEM

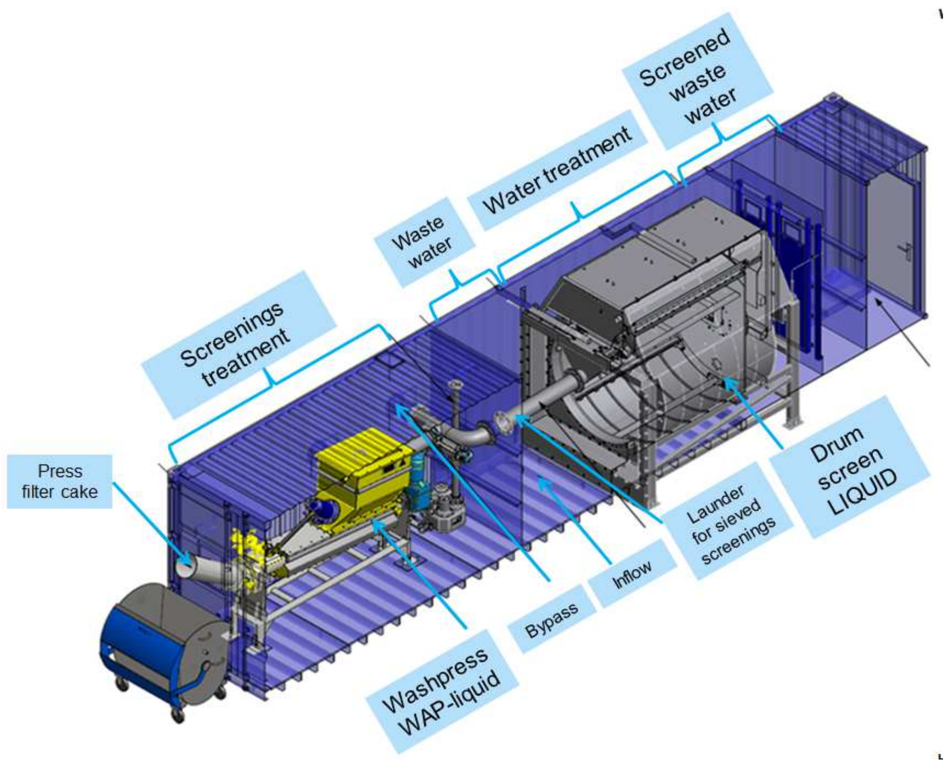

Fig. 7: Container plant E-Klär (BMBF FKZ 02WER1319F) with *HUBER Drum Screen LIQUID* and external *HUBER Screenings Wash Press WAP® liquid* prior to sludge transport into the digester [8]

To achieve the aim of mechanically reducing the loads in the bio-system and replace a preliminary settling tank, a *HUBER Drum Screen LIQUID* was used in place of a preliminary settling tank when changing from an aerobic treatment process to anaerobic treatment with sludge digestion. The *HUBER Drum Screen LIQUID* is a new development that has been designed on the basis of the operation principle of the traditional *HUBER ROTAMAT® Rotary Drum Screen* units. The innovative development uses external screenings treatment and allows for flexibility in location selection for the screenings predewatering system. The screenings can simply be flushed into the screenings press through a pipeline, against the direction of the wastewater flow from the drum screen. Furthermore, a trough with connected pipeline is installed inside the screen drum that provides an extremely flexible and easy solution for screenings transport to the *HUBER Screenings Wash Press WAP® liquid*. The maximum filter surface is optimally used due to the horizontal position of the screen drum and at the same time a very high maximum possible upstream level. Very high throughputs with excellent separation results can thus be achieved. Filterable solids AFS are reliably reduced by 53-60% and COD/BOD5 by 34-41%. These reduction rates are equivalent to that of a preliminary settling tank with a residence time (according to DWA A-131) of 1 h and longer [2; 3].

Fig. 8: Flow to the *HUBER Drum Screen LIQUID* with maximum upstream water level [8]

8. SCREENINGS THICKENING WITHOUT POLYMER

In the *HUBER Screenings Wash Press WAP® liquid* which has especially been developed for the treatment of fine screenings the generated screenings are predewatered to DS contents of up to 10% without the use of any polymers. The dewatering degree can directly be influenced as the *HUBER Screenings Wash Press WAP® liquid* is equipped with exchangeable perforated plates.

A DS content of approx. 3-4% has turned out to be reasonable for the digester. The thickened screenings from the *HUBER Screenings Wash Press WAP® liquid* can directly be delivered into the digester by means of an eccentric screw pump [8].

The screenings separated by the fine screen are flushed into the wash press through a gravity pipeline. A part of the liquid phase can drain off through the very fine perforated plate inside the wash press. The resulting DR content in the fine screenings is 3-4% DR. The free water which is generated through screenings thickening/dewatering in the wash press can be discharged to the influent to the fine screen or optionally to the effluent from the fine screen. If the filtrate that is loaded with COD/AFS is returned to the effluent from the fine screen the total separation degree will be reduced by approx. 6-8% AFS and COD [8].

Fig. 9: Predewatered fine screenings from HUBER Screenings Wash Press WAP® liquid for digestion [8]

Returning the filtrate from the wash press has a major advantage: A partial flow, which can be defined and adjusted via the perforated plate and is highly loaded with carbon, can directly be passed on to the denitrification system in case of a lack of carbon. Of course, also a part of the filtrate water from the wash press could be stored and used as external carbon source when required [8].

9. SUMMARY

One of the major benefits of a fine screening system is significantly reduced space requirements, approximately one tenth of the space required for a primary settling tank, and thus significantly reduced investment costs. Digestion plants have previously been no option for operators of small and medium-sized sewage treatment plants due to low energy prices and high investment costs. This situation will change now due to fine screening and innovations in the field of small biogas plants. With the use of anaerobic sludge stabilisation (sludge digestion) it is possible to generate additional energy and reduce sludge volumes whereas aerobic sludge stabilisation consumes energy as supply for the aerators [1; 3].

Fine screening should especially be considered as an economical and efficient option for upgrading smaller sewage treatment plants without preliminary treatment. Due to the high COD/BOD removal rates that can be achieved with fine screening the load on downstream biological treatment systems can be reduced and their clarification capacity increased. A fine screen with a very fine mesh size can for example reduce COD_5 load by up to 41%. As a result, also the BOD_5 volumetric loading is reduced by up to 41% while clarification efficiency for BOD_5 and COD is increased [2; 3].

If new sewage treatment plants are planned with a fine screening system the aeration tank can be designed by 70% smaller when changing from anaerobic treatment with 11.6 days sludge age (calculation according to ATV A-131) to aerobic treatment with 25 days sludge age. Sludge volume is thus reduced by 30%. In addition, the organic load is reduced through digestion and sludge dewaterability improves, with the result of lower disposal costs, also due to the smaller amount of generated sludge. This article does not further deal with the subject of disposal costs.

After a six-week trial period it was found that reliable automatic plant operation is guaranteed day and night. Due to the very positive results and resulting follow-up inquiries from customers more plant sizes have meanwhile been developed which enable us to implement projects with throughput capacities of more than 600 m³/h.

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