Evaluation of the separation efficiency of step screens from Hydria Water

Test facility at Vårgårda wastewater treatment plant

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1. Summary

The purpose of this study was to investigate the degree of separation of impurities in a further developed step screen from Hydria Water. Tests have been carried out at Vårgårda wastewater treatment plant, in a test facility installed as a backup for existing sewage separation at the treatment plant. The tested screen is model SSD 1100-600-2 with a 2 mm gap width and is designed to be able to operate in both step mode and pulse mode. In this study, only pulse mode was used, where the screen moves in short, incomplete steps, which is an operating mode that reduces the flow of water during movement and promotes the buildup of a screenings mat.

The test setup was designed based on the methodology described in a study conducted at Chalmers University of Technology (Larsson & Andersson, 2005), where both progressive step screens and conventional step screens were evaluated. An important difference between the studies is the collection method of material in the water that has passed the cleaning screen. The Chalmers study used a copasac with a mesh size of 4–6 mm, while this study used perforated metal strainers with 2 mm and 6 mm holes.

Five tests were conducted with varying test duration, flow and strainer size. The Screen Capture Rate (SCR) has been calculated based on both wet weight and dry matter content. The highest SCR values, over 90% based on wet weight, wereachievedatlongertest durations (40 – 45 minutes) and with a 2 mm strainer, which indicatesthat screenings mat buildup is importantforthe separation rate. The two test occasions that gave an SCR lower than 90% were carried out with a shorter test duration due to the capacity of the outlet strainer becoming limiting, which may mean that the screenings mat did not have time to build up sufficiently during the test.

Envidan participated in the study as an independent party with responsibility for documentation and control of the tests.

2. Background

Studies have been conducted at Chalmers University of Technology (Larsson & Andersson, 2005) where the separation rate was examined in three different step screens, manufactured by Meva, Nordic Water AB. Two Monoscreen screens (progressive screens) with 2 and 3 mm gap widths were compared with a traditional Rotoscreen screen (step screen) with 3 mm gap width. The tests were carried out at the Floda wastewater treatment plant and aimed to study how parameters such as flow, gap width, pressure drop and operating mode (pulse or step operation) affect the efficiency of the screens. Theresults showed that the progressive screens could achieve a separation efficiency of up to 81% under optimisedconditionswith pulsemodeand 200 mm pressure drop, while the conventional stepped screenreached52%whenoperated in stepmode. Forthe progressive screens, a separation rate of up to 76% wasmeasuredin stepmode, which shows that theoperatingmode has an impacton the screen's efficiency. Thisstudyconstitutesa central reference inthefield andishereinafterreferred toas the Chalmers study.

Progressive step screens are asymmetrically designed with different sizes of steps. In the lower part, the screen is relatively flat, but the design of the step means that the step lift gradually increases towards the unloading zone. The design is intended to promote screenings mat buildup and efficient screen transport.

Traditional step screens have a construction where all steps have the same design, which provides a constant geometry over the entire length of the screen (linear design). In this way, the waste is transported so that the composition of the screenings mat is preserved during transport.

Hydria Water has further developed its step screens and produced a new model, SSD, where the bottom construction differs from previous models. The strainer rods and steps have the same dimension across the entire transport surface of the screen, but unlike traditional step screens, the bottom step is movable and follows the movement of the screen. This prevents larger openings from occurring in the lower part of the screen during operation. The design of the bottom step is patented, for more information see patent SE0401062. The SSD model has been developed to run with pulse operation, where the screen moves in short, incomplete steps. The purpose of this operating mode is to further reduce the flow through the lower part of the screen during movement, which is expected to promote screenings mat buildup and thereby improve the separation efficiency.

To investigate how this design works in practice, Hydria Water carried out a series of tests with the new screen in pulse mode. The goal was to study its separation capacity and to compare the results with those previously reported in the Chalmers study.

Envidan participated in the work as a controlling function with responsibility for following up, documenting, analysing the tests and writing the test report. Envidan's role can be described as a form of third-party review, with the aim of ensuring that the tests have been conducted in an objective and transparent manner.

3. Theory

3.1 Separation rate

The calculations of the separation rate in this study follow the same methodology used in the Chalmers study (Larsson & Andersson, 2005). There, the separation rate, also called screen capture rate (SCR), is defined as a measure of how effectively a cleaning screen captures solid particles from a wastewater flow.

SCR is expressed as a percentage and is calculated according to the following formula:

$$SCR = \frac{Y}{X} * 100\%$$

where:

X is the total amount of particles in the incoming wastewater

Y is the amount of particles captured by the cleaning screen

Since it is not practically possible to measure **X** directly during a test (because this would require all particles to be removed at the inlet), the theoretical relationship is used:

$$X = Y + Z$$

where:

Z is the amount of particles that have passed through the cleaning screen

By substituting **X** in the original formula, a more practically applicable calculation is obtained:

$$SCR = \frac{Y}{Y + Z} * 100\%$$

This method allows for accurate and reproducible measurement of the cleaning screen's efficiency under realistic conditions.

4. Materials and methods

4.1 Test facility

The tests were carried out in a test facility for wastewater separation at Vårgårda wastewater treatment plant. The facility serves as a backup for the regular wastewater separation at the treatment plant and was supplied by Hydria Water. It is placed in a container and consists of an SSD 1100-600-2 cleaning screen with a gap width of 2 mm, a cleaning washing press, a collection container for cleaning bags and a control cabinet (see Photo 1 and Photo 2). The maximum hydraulic capacity of the cleaning screen is 400 m^3/h.

The level before the screen is monitored by a hydrostatic pressure sensor mounted 210 mm above the bottom. The pressure sensor signal controls the start of the screen at a preset level (510 mm) and with a delay of 0.5 seconds. During the tests, only pulse mode was used, with a pulse time set to 0.25 seconds.

Photo 1 Test facility.

Photo 2 Test facility.

The debris from the screen was collected in a basket with 2 mm hole perforations, placed in the shaft where debris is normally routed to the cleaning washing press (see Photo 3).

Photo 3 Collection basket for debris, 2 mm hole perforations.

Wastewater is pumped into the test facility from the nearest pumping station on the pipeline network. Before the wastewater reaches the test facility, the water is released into an inlet shaft (see Photo 4 and Photo 5).

Photo 4 Inlet shaft.

Photo 5 Inlet shaft.

Wastewater that has passed the cleaning screen continues to an outlet box (see Photo 6) where it is possible to adjust the liquid level after the screen by inserting a plate. During these tests, no sheet metal was used and the water level after the screen was 17 cm.

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Photo 6 Outlet box with the possibility of adjusting the liquid level after the screen.

The flow then continues from the outlet box and is released into the existing channel at the treatment plant. During the test, a strainer (outlet strainer) is installed at the outlet of this pipe to capture particles. During the test, two different stainless steel outlet strainers were used, one with 2 mm hole perforations and one with 6 mm hole perforations (see Photo 7 and Photo 8).

Photo 7 The water is released into the channel.

Photo 8 Outlet strainer for filtering water released into the channel.

4.2 Test method

The test method used in this study has, as far as possible, been designed to mimic the method applied in the Chalmers study (Larsson & Andersson, 2005). The purpose of this is to enable a direct comparison of the results between the studies.

All tests were started with an empty cleaning screen, that is, without a screenings mat. The strainer basket for collecting debris was emptied and installed in the cleaning shaft and the outlet strainer emptied and installed on the outlet line. The test was started by switching on the pump in the pumping station. The pump was controlled with the frequency converter in manual mode so that the pump ran at a fixed speed. This meant that the flow did not vary during each test. The duration of the test began from the moment the pump was started.

At the beginning of the test period, solid particles accumulated on the screen, which gradually built up a screenings mat. When the water level upstream of the screen reached the preset start level for screen operation, the screen was activated and conducted a pulse. The time for how quickly a screenings mat formed varied between the tests depending on the composition of the water.

The total test duration varied between 3 and 45 minutes. In the test with a duration of 3 minutes, the test was interrupted due to the outlet strainer becoming clogged, but in the other tests, the test was interrupted after a predetermined period of time.

When the test was completed, the screen was operated manually to transfer all collected debris to the strainer basket that was placed in the shaft after the screen. Then, both the strainer basket and the outlet strainer were lifted off and placed to drain for 30 minutes.

After the strainer basket and outlet strainer had been left to stand for 30 minutes, the material was emptied into separate buckets, after which the contents were weighed. Samples for dry matter analysis (dry weight) were taken and stored in airtight sample containers for later analysis. A KERN DAB scale with a built-in halogen lamp, model 100-3, was used to measure dry matter.

5. Results

A total of five tests were performed with varying test duration, water flow and outlet strainer hole size. Table 1 summarizes the results from these tests.

Table 1 Compilation of test results.

	Test duration	Flow	Outlet strainer hole size	Wet weight cleaning screen	Wet weight material outlet strainer	TS content debris from screen	TS content material outlet strainer	SCR (wet weight)	SCR (dry weight)
	min	m3/h	mm	g	g	%	%	%	%
Test 1	15	89	2	1933	677	11	16	74	65
Test 2	3	79	2	1966	1085	19	11	64	75
Test 3	45	92	6	2718	13	14	11	99.5	99
Test 4	40	92	2	581	61	11	19	90.5	84
Test 5	40	94	2	807	84	11	17	91	86

In test 1, a 2 mm outlet strainer was used. The flow was 89 m^3/h and the test was stopped after 15 minutes because the outlet strainer was then starting to become so filled with debris that it would have started to overflow if the test had continued. The separation efficiency was 74% basedon wetweight, while the SCRcalculatedfromdry weight was 65%. The difference between SCR (wetweight) and SCR (dry weight) can beexplainedby thehigherwater content in thecaptureddebris.

Test 2 had to be interrupted after just 3 minutes because the outlet strainer quickly filled with debris and the flow was obstructed. The flow was slightly lower, 79 m^3/h. SCR was 64% (wetweight) and 75% (dry weight). The short test duration probably meant thatastable screenings mat did not have time to form, which negativelyaffectedthe separation efficiency. The higher SCR based on dry weight indicates that the material captured in the outlet strainer had a high water content compared to the material trapped in the screen.

In test 1 and test 2, the debris had a different character compared to the other tests. A visual assessment indicated that the debris contained more fat and fibres compared to the other test occasions, which quickly clogged the outlet strainer.

In test 3, a coarser 6 mm outlet strainer was used. The test lasted for 45 minutes with a flow of 92 m^3/h. SCR was measured at 99.5% (wetweight) and 99% (dry weight). The largeholesize in the strainer may haveallowedverysmall particles to pass through,thusgiving alowZvalue. The resultsshouldthereforebeinterpreted withsomecaution.

Test 4 and test 5 were conducted under similar conditions with a 2 mm outlet strainer, flow of 92 and 94 m^3/h, respectively, and a test duration of 40 minutes. SCR was measured at 90.5% and 91% (wetweight), respectively, while SCR basedon dry weight was 84% and 86%, respectively. Thelongtest duration gave the screenings mattheopportunity to stabilise, which probablyexplainsthehighvalues. In both of these tests, the setpoint level before the screen was reached after about 33 minutes and the screen then pulsed, which lowered the level. No more pulses were needed within the time the two tests were running.

6. Discussion

The results in this study have been compared with those reported in the Chalmers study (Larsson & Andersson, 2005), where different types of cleaning screen were tested under similar conditions. An important methodological difference between the studies concerned the collection equipment for the particles that pass through the screen. The Chalmers study used a copasac, a soft mesh bag with a specified mesh size of 4–6 mm, while this study used perforated stainless steel strainers with hole sizes of 2 mm and 6 mm, respectively. The difference in materials and construction between these collection units affects the ability to make direct comparisons of the separation efficiency (SCR).

Because the copasac is made of a flexible material, its actual opening size may vary during the course of the test. The load of the debris, water flow and movement in the net can cause the meshes to stretch or compress, making it difficult to accurately assess the size and amount of material passing through it. This leads to an uncertainty in the estimate of the amount of material passed (Z) and thus in the calculation of SCR.

Even perforated strainers have certain limitations. Despite having a defined hole size at the start of the test, the debris can begin to clog the holes during the test, affecting the flow rate and in practice changing the effective opening area. However, this variation is more predictable than with a soft mesh, making perforated strainers more suitable in this type of test. When a strainer with a smaller opening, such as a 2 mm, is used, a larger proportion of the material will likely be captured compared to a strainer with a larger opening. This means that these tests do not overestimate the degree of separation in any case in comparison with the tests carried out in the Chalmers study.

Among the factors that appear to have had the greatest impact on the separation rate in this study are the duration of the test and the screenings mat buildup. In test cases with shorter test durations, lower SCR values were observed, which may be due to the screenings mat not having had time to become established. In tests of longer duration, however, SCRs above 90% were measured, indicatingthat a stable screenings mat acts as asecondaryfilterthatimprovesseparation efficiency.

The flow was relatively constant between the tests (79–94 m^3/h), which means that its impact cannot be analysed in detail in this study. However, it can be noted that flows within this range appear to have allowed stable operation and screenings mat buildup. The flows at which the tests were carried out correspond to approximately 20-24% of the screen's capacity. The tests reported in the Chalmers study were carried out in the range of 12.5-50% of the screen capacity. The hydraulic load on the screen in this test was thus on par with the hydraulic loads tested in the Chalmers study.

One factor that was found to affect the degree of separation in the Chalmers study was the operating mode. In that study, both pulse mode and step mode operation were tested, but only the progressive screens (Monoscreen) were operated in pulse mode. The step screen (Rotoscreen) that was included was only tested in step mode, which means that its function in pulse mode was not evaluated.

In this study, however, a step screen without a progressive design has been operated in pulse mode, which makes it possible to also investigate how this operating mode affects the separation capacity for this type of screen. Pulse mode means that the screen moves in short, incomplete steps. This reduces the area of the screen that is free of screenings mat with each movement, compared to if a full step had been taken. This also means that the time the bottom step is open is shortened, which can limit the flow of particles that otherwise risk passing through without being captured. In the Chalmers study, longer flow time through an open bottom step was cited as one of the reasons why the progressive screens (Monoscreen) performed better when operating in pulse mode than in step mode.

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It can also be assumed that the design with a movable bottom step affects and contributes to a higher degree of separation, since it follows the movement of the lowest rod assembly, which means that the nominal gap width is maintained even during step movement.

The results from this study show that Hydria Water's SSD model step screen, with a movable bottom step and operation in pulse mode, can achieve a separation efficiency of around 90%. This isahigherseparation thanthe progressive screen tested in the Chalmers study.

The high separation rate is likely due to the design and operating mode of the screen, as the movable bottom step and pulse mode are expected to have contributed to more efficient debris separation and a stable screenings mat. However, the results may also have been affected by other circumstances, such as the composition of the debris and the different test conditions.

In the tests that lasted 40-45 minutes, the first pulse came after about 30 minutes. In comparison to continuous operation, this means that the results are affected for a greater proportion of the time by either screenings mat buildup at start-up or any rebuild-up of screenings mat at the bottom edge of the screen after the pulse. This means that the SCR during continuous operation of the screen should be higher than during this type of test. Similar phenomena should have affected the results from the tests conducted in the Chalmers study.

7. Conclusions

In these tests, Hydria Water's SSD step screen model achieved a separation rate of around 90% based on wet weight when operating in pulse mode.

This is a better separation than previously measured for the three step screens tested in the Chalmers study. The improvements that have been implemented in the SSD screen have likely contributed to the high separation rate. When comparing the results with those from the Chalmers study, however, it must be taken into account that the composition of the debris may also have affected the results.

In tests shorter than approximately 45 minutes, the time before the screenings mat has built up at the beginning of the test can negatively affect the total separation rate during the experiment.

Deviating water with a lot of fat and fibre negatively affected the measured separation rate in one of the tests.

8. References

Larsson, N. & Andersson, O., 2005. *Screening of sewage water, study of screening efficiency of step screens*. Degree project. Chalmers University of Technology, Department of Chemical and Biotechnology.

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