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# Effect of coupling primary sedimentation tank (PST) and microscreen (MS) to remove particulate organic carbon (POC): a study to mitigate energy demand in municipal wastewater treatment plants

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**Abstract**

Particulate Chemical Oxygen Demand (COD) removal is one of the first and foremost steps in a wastewater treatment plant (WWTP). It is a highly essential step that supports subsequent biological steps to achieve discharge limits. However, the energy demand for subsequent biological steps is significant due to the requirement of physical processes such as aeration. As a part of the project: WWTP of the future, it was expected that by coupling primary sedimentation tank (PST) and microscreen (MS) as advanced primary treatment (APT), around 60 to 70% removal of total COD and more than 90% of total suspended solids could be achieved which can replace such energy-intensive steps. To achieve this, a pilot plant set up including two different types of rotatory drum sieves (8 and 20 µm) was coupled with a PST in the WWTP Büsnau, Stuttgart, Germany, and the efficiency of APT was undergone for deeper investigations. The results showed that applying APT processes is an innovative and robust approach for removing more solids in municipal WWTPs so that retrofitting treatment plants comes true with a marginal footprint. However, the long-term performance of the APT system demonstrated that the system's ability to remove solids is highly limited by MS capacity and strength of produced flocs/filter-cakes inside the MS against shear forces, which makes it easier for flocs to be detained by MS. Therefore, additional auxiliary steps like flocculation are recommended to be synchronized with APT system to enhance its efficiency. Additionally, applying a middle mesh size sieve, for instance, a 15 µm, along with changing the backwashing regime, could be considered the next alternative.

**Keywords** Advanced primary treatment, Microsieving, Primary sedimentation, TSS, Particulate COD

## 1 Introduction

Technologies like conventional activated sludge (CAS) have mainly been applied to treat municipal wastewater. Nevertheless, this process is costly because of the extensive operations and maintenance costs, for instance, running the aeration and sludge disposal facilities. In addition, leaving a large carbon footprint is unavoidable in this process. Therefore, wastewater treatment in energy-efficient ways is getting more attention due to costs and the carbon footprint of water resources and recovery facilities [1]. Remy et al. [2] proved that raw sewage's energy potential is five times bigger than the expected power for its treatment. Their calculations revealed that developing an energy-positive wastewater

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treatment plant (WWTP) should be feasible. Indeed, a WWTP for which energy recovery is higher than its energy consumption. Mainly, WWTPs were designed to partially remove organic matter (only a portion of Chemical Oxygen Demand (COD), not dissolved COD) through sedimentation tanks. Because of population growth and stricter discharge criteria, several WWTPs will deal with the challenges of upgrading. So far, the common practice has been constructing more tanks for such an upgrade. However, for this purpose, vast land is not always available. In addition, in most cases, it is impossible to extend WWTP to an adjacent area because of restrictions. Therefore, it has been an extending interest in upgrading WWTPs by establishing fine mesh sieves for primary treatment. And then employing the prevailing sedimentation tanks for diverse uses [3]. Microscreens (MS) are gravity-driven and self-cleaning systems constructed to realize high-performance solid separation with a minimum footprint and low energy consumption. MSs are delivered as either disc or drum filters [4]. It was not a long time ago when microfiltration was introduced for wastewater treatment for the first time, according to the literature review. Diaper and Glover [5] worked on the design, operation, and evaluation of microstraining, followed by tertiary treatment steps, of a combined sewer overflow in the US. The applied MS was a stainless-steel drum sieve (DS) with a 1.5 m diameter by 0.9 m long. In their study, two different screens were tested, namely 35 and 23 µm. They measured the removal efficiency of MS for Suspended Solids (SS), ranging from 13 to 98% depending on the adjusted rotational speed of the DS. Cheung et al. [6] studied the SS removal efficiency of an MS compared with that of the conventional primary sedimentation tank (PST). They found that the MS was very efficient in eliminating SS compared to the conventional PST in dry weather. Later on, MS was applied as an advanced treatment in WWTPs to meet new set discharge limits. For instance, in Germany, Grau et al. [7]. tested different drum sizes varying the mesh sizes to 10, 20, and 40 µm after the secondary sedimentation tank. They recorded a SS retention of 75 to 85%. In addition, Wilen et al. [8] applied disc filters to deepen the knowledge of the potential of eliminating different wastewater components to fulfill stricter effluent discharge limits of total phosphorus removal. Razafimanantsoa et al. [9] discovered that high solids removal during primary treatment by application of MS has no considerable consequence on the downstream denitrification process. Recently, researchers [10–15] focused on combining chemical dosing (coagulation-flocculation) with microfiltration as an enhanced primary treatment (EPT). Reviewing the literature reveals that nobody came across to think about extracting as much organic matter as possible and reducing the carbon load for the subsequent stages of treatment through a low-energy EPT by coupling PST and MS. Therefore, this study aimed to have a deeper understanding of this subject. For this purpose, in WWTP Büsnau, Stuttgart, Germany, the raw sewage, after mechanical pre-treatment, grit removal, and settling by PST, was subjected to the filtration process by two different DSs, 8 and 20 µm mesh to separate the particulate organic matter (POM) efficiently and the formed filter cakes. The configuration is called advanced primary treatment (APT); however, without any chemical addition.

## 2 Materials and methods

### 2.1 Materials

Half-scale tests were conducted at WWTP Büsnau (10.000 Population Equivalent), Stuttgart, Germany, using only drum MS with different mesh sizes from two manufacturers. An 8 µm DS from the company Veolia Water Technologies AB Hydrotech (Paris, France) (MS-TS1) and a 20 µm DS from the company Huber Technology (Bayern, Germany) (MS-TS2) were tested in situ after the PST unit. It is worth mentioning that the pilot plants have been under inspection for many months, and only the results presented in this study when there were no major technical problems.

#### *2.1.1 Mesh size selection*

Various fine mesh sieves, including rotating drums, discs, and belt sieves, can be found on the market. Principally, the filtering efficiency is influenced by the size of the MS. The study by Askari Lasaki et al. [16] proved that the mesh size of MS should be selected between 4 and 20 µm for the maximum extraction of particulate organic carbon if an MS is coupled with a PST in municipal WWTPs. Therefore, in this study, two different mesh sizes, which align with mentioned criteria, were used, following a finer (MS-TS1) with a mesh size of 8 µm and a course (MS-TS2) with a mesh size of 20 µm.

#### *2.1.2 MS-TS1*

After passing the grit and grease chamber and being settled by a rectangular PST, raw municipal wastewater was entered into the MS unit, and finally permeate of MS was collected in an equalization tank. The drum filter was equipped with stainless-steel media with a sieve pore size of 8 µm (filter area 3744 $cm^2$). The flow rate was adjusted by a pump from Netztch Gruppe, type: NM031BY (Selb, Germany), and controlled by an electromagnetic flowmeter from Endress+Hauser (Reinach, Switzerland). Technical water (200 to 600 kPa) was used for backwashing (BW). Figure 1 displays the pilot plant with all applied units for running MS-TS1.

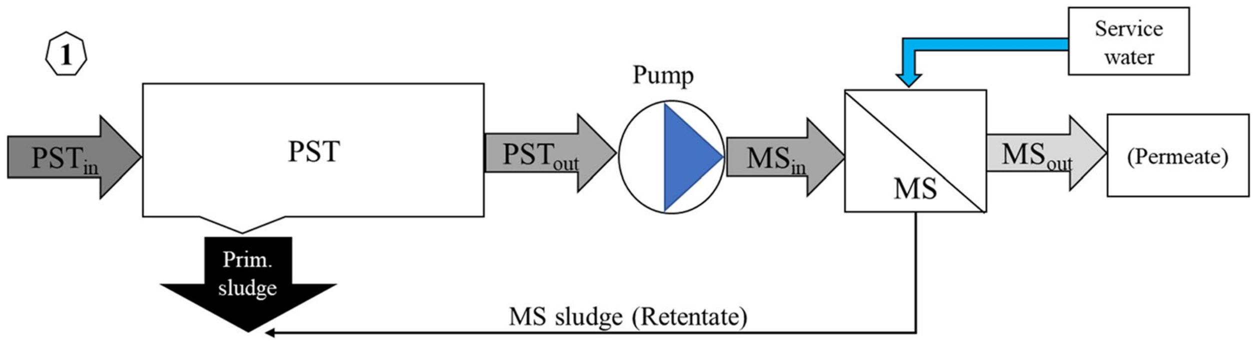


**Fig. 1** Pilot plant for running MS test, MS- TS1 (8 µm)

#### *2.1.3 MS-TS2*

Since the trial with the 8 µm sieve was not highly satisfactory, the 20 µm sieve was chosen for further investigation. Due to the weather, running other tests in situ was not easy. Therefore, it was decided to conduct experiments for the 20 µm sieve in a test hall. Likewise, raw municipal wastewater which passed the grit and grease chamber was used. Raw sewage was collected in an equalization tank with intense mixing and pumped through a pump from Netztch Gruppe, type: NM031BY (Selb, Germany), to the PST, a cone shape with a capacity of 2 $m^3$. Afterward, pre-treated wastewater was entered by gravity into the MS unit and finally collected in an equalization tank (volume: 1 $m^3$). The DS was equipped with stainless-steel media with a pore size of 20 µm (filter area: 7065 $cm^2$). An electromagnetic flowmeter from Endress+Hauser (Reinach, Switzerland) controlled the flow rate. Technical water (max. 500 kPa) was applied for the BW. Figure 2 shows all the units used for the new configuration of the pilot plant for MS-TS2.

**Remark:** The main difference between the function of MS-TS1 and MS-TS2 was that MS-TS1 was equipped with hydrostatic pressure (BW sensor) and rotational speed change facilities.

#### *2.1.4 Sampling*

Grab samples were considered for the analytical analyses because the flow rates in WWTP Büsnau were not constant; therefore, composite sampling based on flow would not be representative. Moreover, the Total Suspended Solids (TSS) concentrations, organic matter, and turbidity varied during the days, so capturing every fluctuation in wastewater concentration would have been nearly impossible. However, some 1-h composited samples were collected by hand on an equal volume basis only to evaluate the shear forces' effect on the effluent quality of MS.

### 2.2 Methods

To evaluate the removal efficiency of used MSs after coupling with PST, grab and mixed samples were taken from the inflow and outflow of PST and MS during different time intervals. After taking the samples, they were subjected to multiple analytical analyses, including turbidity, TSS, Total Solids (TS), COD, and Total Organic Carbon (TOC). The measurements were conducted according to German standard DIN and are as written in Table 1.

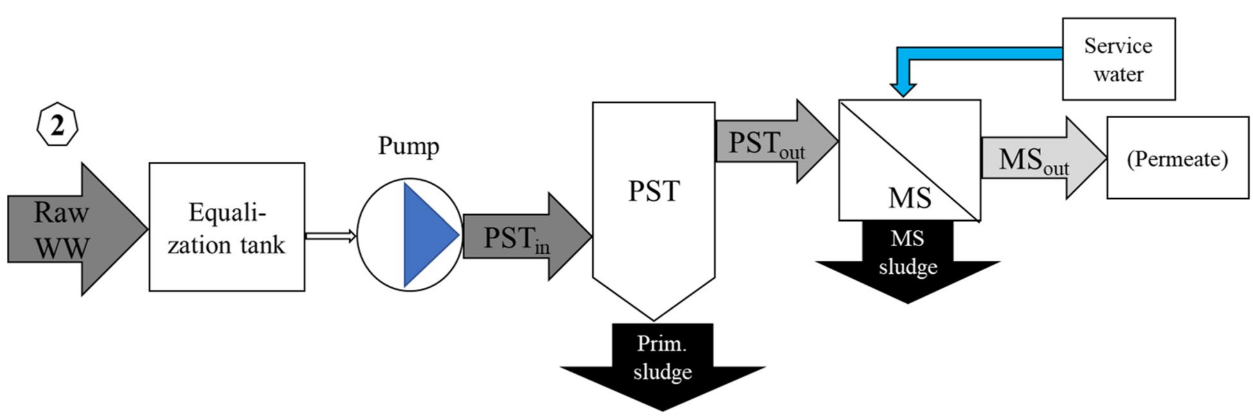


**Fig. 2** Pilot plant for running MS test, MS-TS2 (20 µm)

**Table 1** Standard used for conducting analytical analysis

| Parameter | TSS | COD | TOC | TS |
|---|---|---|---|---|
| Standard | DIN 38409-2 | DIN 38409-41 | DIN EN 1485 | DIN 38409-1 |

Turbidity: by turbidity meter from the company Endress+Hausern (Reinach, Switzerland)

### 2.3 Interpretation of data

The removal rate (R, %) of each term, for instance, TSS, was determined according to Eq. (1).

$$R(\%) = \frac{C_{in} - C_{out}}{C_{in}} * 100 \quad (1)$$

where $C_{in}$(mg $L^{-1}$) represents the inflow concentration, and $C_{out}$ (mg $L^{-1}$) represents the outflow concentration.

For measuring the total removal efficiency ($R_T$) of APT, Eq. (2) was applied.

$$R_T(\%) = R_{PST} + R_{MS} \quad (2)$$

where $R_{PST}$(%), and $R_{MS}$(%) are the removal rate of PST, and MS, respectively.

To determine the effects of implementing different flux (q, L $h^{-1}$ $cm^{-2}$) on the efficiency of the MS system, Eq. (3) was used.

$$q\left(L\ h^{-1}cm^{-2}\right) = \frac{Q_{in}}{A_{eff}} \quad (3)$$

Where $Q_{in}$ (L $h^{-1}$) shows the inflow rate to the MS and $A_{eff}$($cm^2$) reflects the effective area of filtration inside MS., It should be noted that the whole area of MS ($A_T$) should not be considered as a basis for the calculation because in DSs only the effective area ($A_{eff}$) contributes into the filtration process. Indeed, $A_{eff}$is the area where when fully submerged with water, BW is started. $A_{eff}$is defined based on $A_T$ by Eq. (4) as follows:

$$A_{eff}\left(cm^2\right) = f * A_T \quad (4)$$

Coefficient $f$ is defined as follows:

$$f = \frac{h_B}{D}$$

Where $h_B$ represents the height of the point at which BW is started, and D is the diameter of MS.

For load calculations, Eq. (5) was used.

$$Load\left(kgd^{-1}\ or\ g\ min^{-1}\right) = Q_{in} * C_t \quad (5)$$

Where $C_t$(mg $L^{-1}$ or g $m^{-3}$) presents the concentration for the time interval of t.

## 3 Results and discussion

### 3.1 Flux and frequency effect

The TSS removal efficiency is the most critical standard to be met by the MS. Distinct factors affecting the TSS removal efficiency are hydraulic capacity/flux ($m^3$ $m^{-2}$ $h^{-1}$) and rotational speed of drum/frequency of MS. To adjust fluctuating hydraulic conditions; the MS-TS1 has an operated automatic control system that maintains a relatively constant head loss across the MS by regulating the frequency. Holding the rotational speed of the drum (frequency) based on revolution per minute was only adjustable in MS-TS1. The results (Fig. 3a) showed that MS is susceptible to frequency change, and the system cannot be run with an arbitrary frequency value. To a certain extent, the increasing frequency positively affected the performance of MS. However, after this point, adverse effects appeared as redundant BW and mixing part of inflow with retentate. This argument is in line with the work done by Bliss [17]. To evaluate the effect of flux on the performance of two selected MS, they were investigated across various hydraulic loadings of 1.0 to 6.0 m $h^{-1}$ (Fig. 3b), corresponding to solids loadings of 200 to 1200 g TSS $m^{-2}$ $h^{-1}$. The performance assessment highlighted that a maximum hydraulic load of 3 and 5 m $h^{-1}$ is suitable for running MS-TS1 and MS-TS2, respectively. Below these values, the systems showed BW limitations within the applied hydraulic loadings. Indeed, BW would happen so often that, in the end, there was not a rational balance between treated water by MS and water used for BW. So, in this case, the redundancy of BW is a decisive factor and plays a vital role in MS's efficient running. In agreement with the negative effect of high flux on the performance of MS, Rusten and Odegaard [18] proved that rotating belt sieves with 350 µm mesh size should be run under enough produced filter mat and specific hydraulic load (25 $m^3$ $m^{-2}$ $h^{-1}$). In addition, Ljunggren [19] proposed some standards for running 20–25 µm MS efficiently in his literature review. The optimum hydraulic loadings proposed in his study were 12–25 m $h^{-1}$ based on the submerged drum filter area.

### 3.2 TSS, TS, COD, and TOC removal

Reductions of TSS, COD, and TOC in the samples after primary treating and microsieving are illustrated in Figs. 4, 5 and 6, respectively.

#### *3.2.1 TSS and TS removal*

Figure 4 shows the SS removals for PST and MS-TS 1 and 2. TSS removals for the study period ranged from

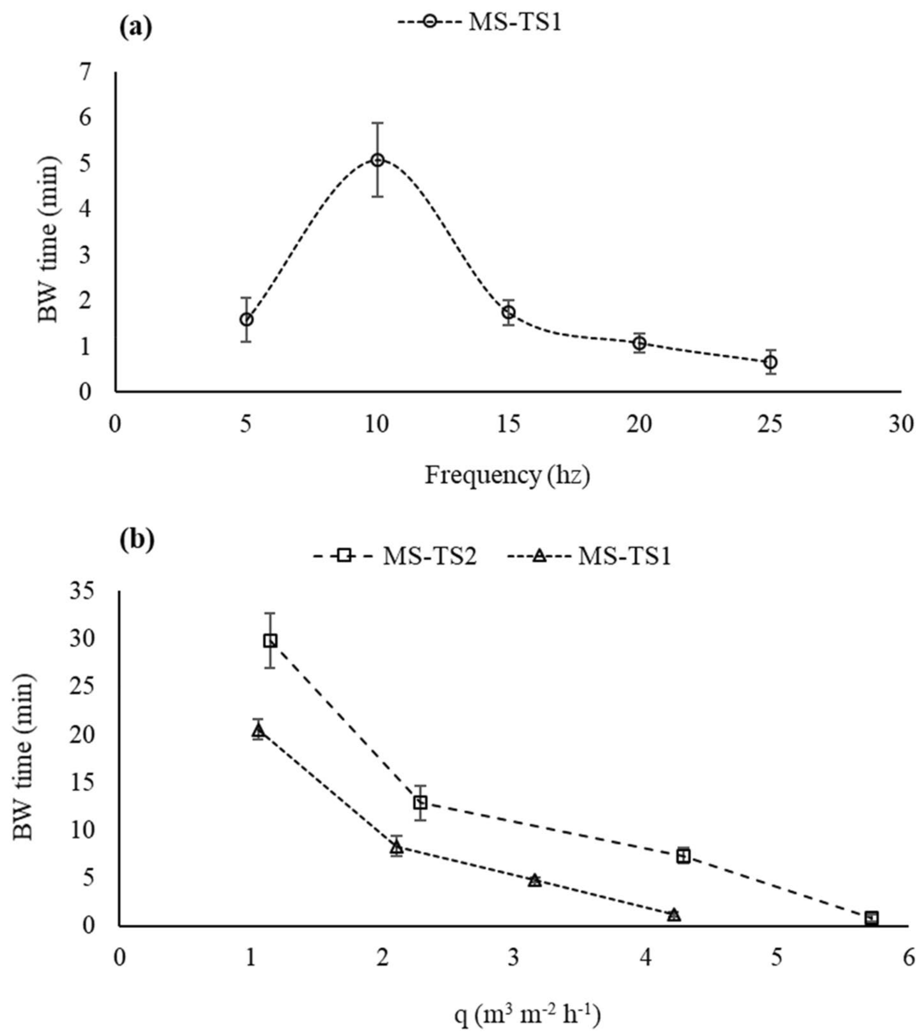


**Fig. 3** Effect of frequency (**a**) and surface loading (**b**) on the performance of MS

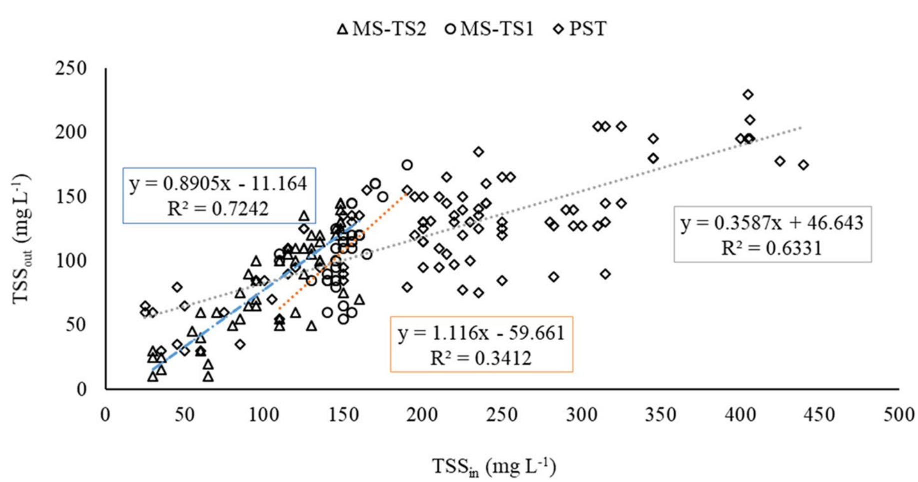


**Fig. 4** TSS removal by PST, MS-TS1 (8 μm), and MS-TS2 (20 μm)

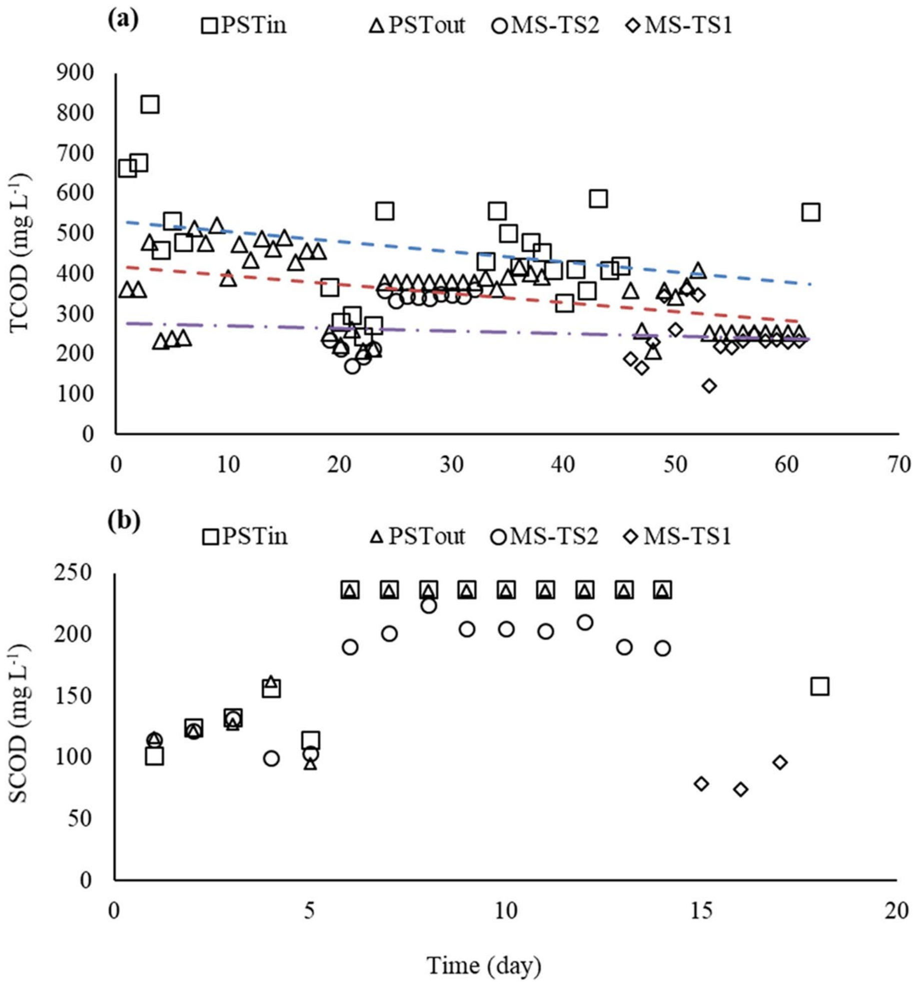


**Fig. 5** TCOD (**a**) and SCOD (**b**) removal by PST and MS

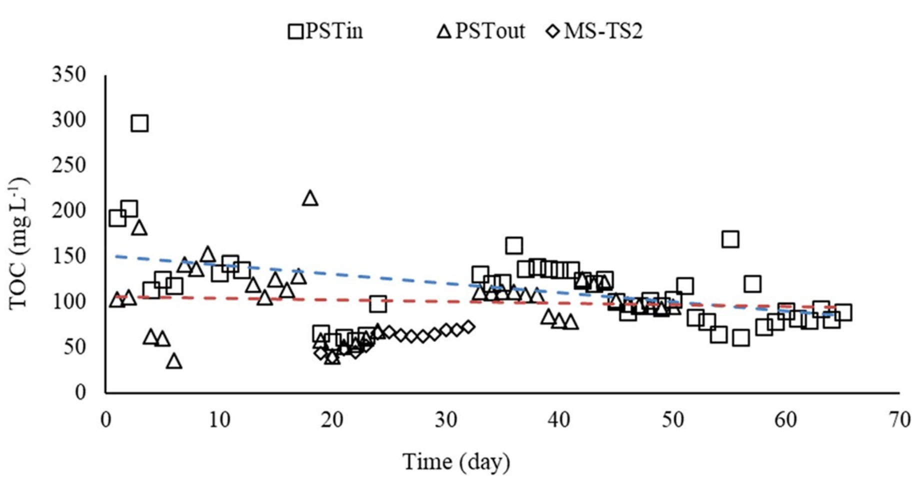


**Fig. 6** TOC removal by PST and MS-TS2 (20 μm)

20 to 60% for PST, 30 to 70% for MS-TS1, and 10 to 50% for MS-TS2. Other researchers have also reported the same range for TSS removal by PST [20–22]. Due to significant leakage and BW problems on MS-TS1, only data on the days were analyzed when there was little or no leakage problem. By evaluating the frequency distribution of TSS removal for MS-TS1 and MS-TS2, it is revealed that approx. 30% and 20% can be achieved as extra TSS removal efficiency when PST is coupled with MS-TS1 and MS-TS2 in the given order. However, when operational considerations are considered, it is concluded that it is not worth using finer meshes only to get a bit more removal efficiency. Therefore, for future reference, selecting the size of meshes is recommended to be considered based on convenient operation rather than achieving higher removal efficiency. Like the results, Hey [23] analyzed the results of the DSs and found that as the sieve pore size decreased (from 100 to 40 and down to 30 μm), the SS removal increased. In contrast, he did not mention the technical problems faced by running finer sieves.

**Remark:** Several tests were conducted for TS measurement as well. However, since TS measurements also consider minerals like salts, it would make a rational interpretation of the results difficult. Thus, this measure was not considered for further evaluation.

#### 3.2.2 COD removal

Statistical analysis (Fig. 5a) showed that PST has a noticeable impact on the reduction of concentrations of COD (approx. 25 to 30%). Contrarily, microsieving offered to have the minimum effect on Total COD (TCOD) removal. However, results demonstrated that the APT system could reduce TCOD to approximately 50%. The reduction is much higher than reported values [24] for APT without chemical treatment, such as flocculation-coagulation. And even the results were relatively close to the removal efficiency of some chemically EPT methods [25].

A deeper look at the results presented in Fig. 5b for soluble COD (SCOD) revealed a different interpretation. There was no significant difference in means for percentage reductions in SCOD of PST. However, by microsieving, a remarkable difference was observed in this perspective. And the finer the sieve, the more this reduction was. The reason is the absorption effect of filter cake produced inside MS, which can remove dissolved organic matter besides particulate ones. In contrast, previous studies like Vaananen [26] claimed that MSs could remove only particulate COD, and nothing was reported about SCOD removal through filter cake. It is worth mentioning that the finer sieve used in his research study was 30 μm.

#### 3.2.3 TOC removal

Figure 6 shows the TOC analyses from grab samples during the trials, and the data displayed a good correlation with TCOD values. The TOC results suggest a 20–25% reduction during average conditions for PST. However, for MS-TS1, it was discovered that the decline is in the range of 15 to 20%. The previous sections showed that MS-TS2 could eliminate only POM; therefore, this reduction is in an acceptable range, and a linear correlation can be drawn between particulate COD and TOC removal in MS applications with coarser meshes. Generally, by considering the application of the finer sieve (MS-TS1), APT can remove approx. 50% of TOC.

### 3.3 Achievable retentate

As achieving a high quantity of MS sludge (retentate) was very important in this study for further applications, so a proper determination of the amount produced was fundamental. Therefore, a precise mass balance (Fig. 7) was calculated for a short interval (during two consecutive BWs, 6 min) using composited samples for the MS-TS2. For this purpose, the flow rate was measured multiple times during two consecutive BWs. Then, the volume of filtered water (permeate) and water detained inside MS were mathematically estimated. It is noteworthy due to the high fluctuation in the permeate flow rate; it was divided into two distinct parts; after BW (laminar condition) and during BW (turbulent state). The calculations revealed that out of approx. 0.72 g $min^{-1}$ catchable retentate, only 0.12 g $min^{-1}$ ended up in the retentate tank. The rest amount found its way to the effluent of MS right immediately after BW because of high shear forces produced inside DS. When BW begins, the DS starts to rotate quickly, leading to shear forces and breakage of produced flocs. Finally, these shredded flocs find their way through free and cleaned pores and reach themselves into the effluent of MS. Therefore, the removal efficiency of MS was reduced immensely. This problem might be solved by applying gentle BW by reducing the drum's rotational speed or making it adjustable.

### 3.4 Operational observations

Since APT is a combination of PST plus MS, and PST is an established method, the focus of this part would be only on technical problems faced by the core of the APT system (i.e., MS). The followings are some operational problems observed during the running of MS-T1, and MS-T2, respectively.

Due to frequent fouling problems, a high-pressure water jet (power: 12–20 MPa) was required for surface cleaning

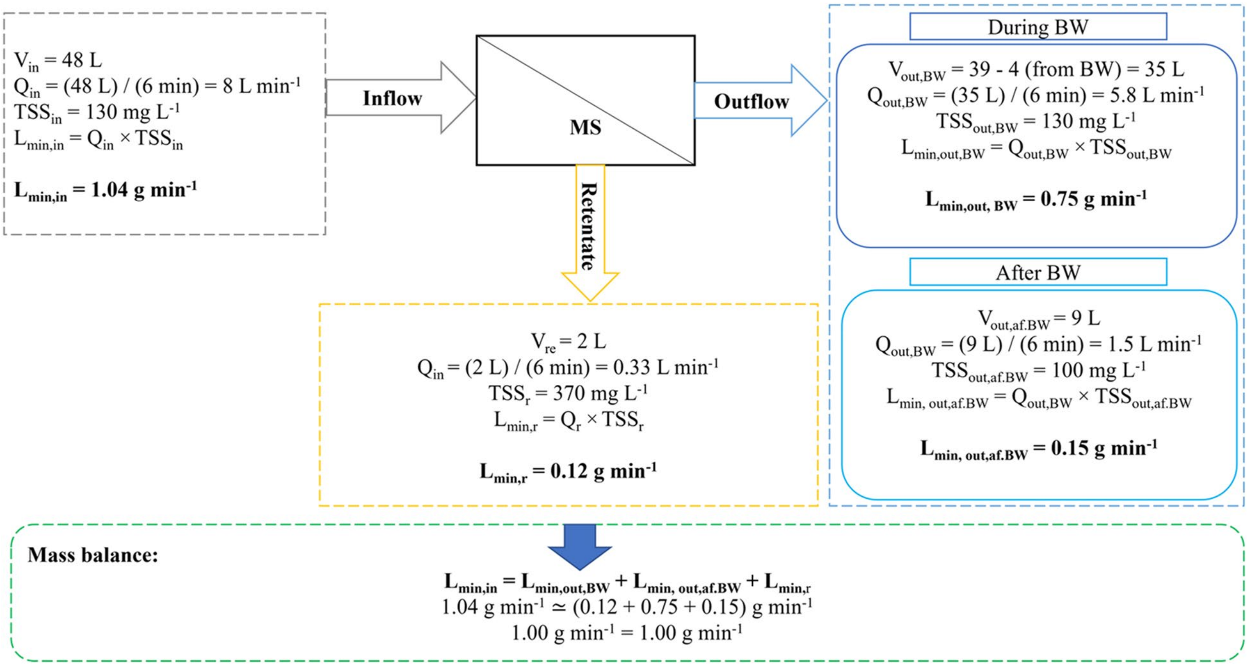


**Fig. 7** Mass balance for MS-TS2 (20 µm) during two consecutive BWs

of DS occasionally. Since clogging of the pores happened quickly, there was a need for service water for BW, so there was no rational balance between treated water and water used for BW. In addition, The MS could not tolerate inflows over 600 L $h^{-1}$, and it was almost impossible to get concentrated retentate. Furthermore, leakage from the edge of the drum was one of the dominant problems. Nevertheless, some solutions were also applied to tackle the MS-TS1 problems, like reducing the distance between the waterjet and the filtration surface to improve BW and using a high-pressure cleaner to clean clogged pores. However, they did not show an efficient effect.

Regarding MS-TS2, the handling was much easier; however, some problems were observed during the running period, as the blockage of pores happened after two days and six weeks for an inflow of 0.5 $m^3$ $h^{-1}$ and 1 $m^3$ $h^{-1}$, respectively. A high fluctuation was detected in hourly/daily TSS removal because of variations in weather conditions, also for TSS concentration, in a way that the higher the TSS concentration, the lower the removal was. BW duration varied from 4 to 45 min according to the TSS concentration. Small pieces of the filter cake (filter mat) were detected in the outflow of MS after BW due to the shear forces effect. The MS could not tolerate inflows over 1000 L $h^{-1}$ (limited flux) for a long duration. In addition, cleaning MS with a 12–20 MPa high-pressure machine was necessary after the blockage of pores.

Since fouling of pores and particle breakage due to shear forces were dominant problems observed by running two MSs and reported by many researchers, two following subsections were allocated to understand these issues deeply.

#### *3.4.1 Fouling problem*

To understand how fast the pores are getting blocked, several tests were done to determine the changes in the flow rate during two consecutive BWs (Fig. 8), which indicates the fouling of the pores. It is seen that the filtration capacity immensely reduced after 3 min from approx. 7 L $h^{-1}$ to less than 1 L $h^{-1}$. This quick fouling can stem from the lipid-containing particles which stick to the pores and reduce their size or even block them. This situation continues until no free pores are available and the water level inside MS has reached the leveled sensor for BW. Here, BW will start, and this cycle will be continued to a specific extent. It should be noted that in every BW cycle, some pores can only be cleaned partially. That is why the capacity of MS is reduced somewhat per cycle, and finally, in cycle N, a complete blockage of pores happens, and the system will not be in operation anymore. In this case, the system should be immediately cleaned, either chemically or physically. In this study, cleaning with a high-pressure jet machine was applied because of its easy handling. Because of the frequent MS fouling problem, washing with a high-pressure jet machine (12–20 MPa) had to be employed occasionally. Soon was figured out that a high-pressure jet (approx. 20 MPa) could slightly

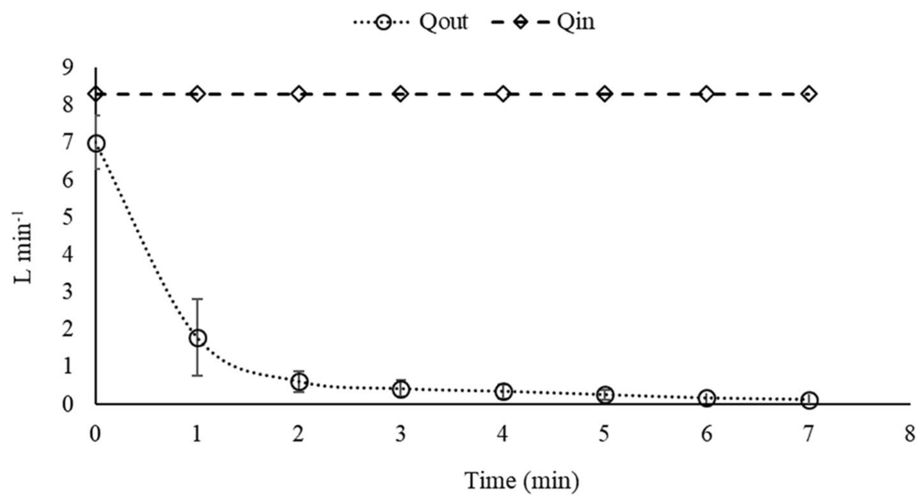


**Fig. 8** Permeate flow rate for MS-TS2 (20 μm)

change the arrangements of MS fabrics and increase the initial size of the mesh. So, lower water pressures, for instance, maximum till 12 MPa, were employed for further trials.

### *3.4.2 Particle/flocs breakage*

A few researchers have reported particle/flocs breakage due to shear forces; however, the breakage mechanisms should be meticulously figured out. Therefore, for a deep understanding of this phenomenon, several composited samples were taken instead of grab samples into consideration. During one hour of sampling, one liter of wastewater was collected every 10 min for the inflow and outflow of MS, and finally, they were mixed and homogenized. Notably, the MS outflow samples were divided into two types; right after BW (turbulent state) and between two BWs (laminar condition). The volume of water treated (permeate), water trapped inside MS (Fig. 9), TSS content, and turbidity of different samples were measured. It is estimated that flocs breakage happened in two distinct phases. First, during BW, water pressure will shred the flocs to smaller pieces, and since the retentate hopper cannot detain all the flocs, the rest will go through free pores and end up in the outflow of

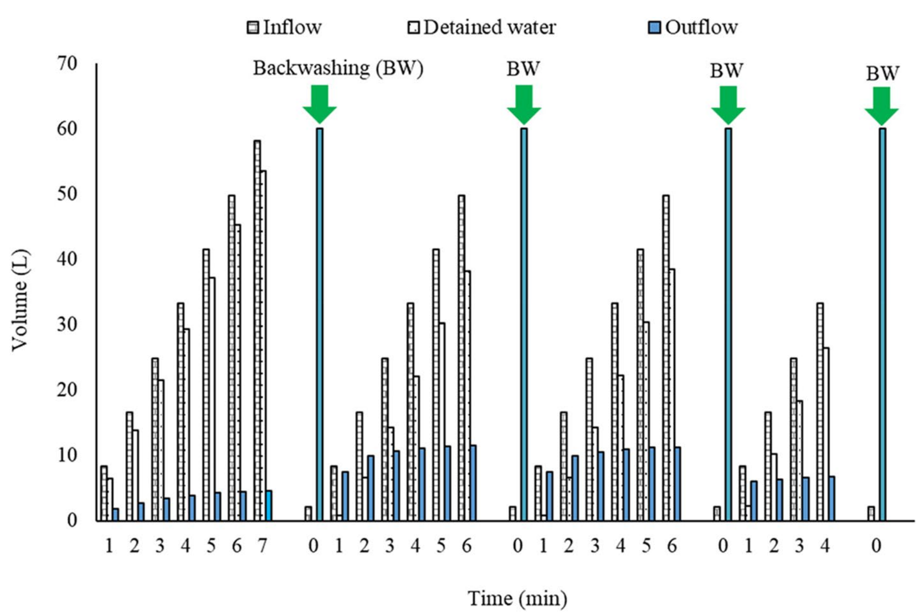


**Fig. 9** Permeate and detained water volume by MS-TS2 (20 μm)

MS. Secondly, the high rotational speed of the DS, which starts by BW may lead to shear forces. It could also be due to the DS's centrifuging nature, which introduces unwanted inertial shear forces to the flocs. The solutions could be either dropping down the rotational speed of the DS during BW or applying different art of MSs like disc filters. A driving force to introduce the shredded flocs in the effluent of MS could be generated hydrostatic pressure by a high amount of water trapped inside MS. So, this amount of water which contains destabilized or shredded flocs, is released exactly right after BW. It will increase the amount of TSS and turbidity in the effluent of MS. This was also confirmed by turbidity and TSS measurements in this study.

### 3.5 Sustainability of APT system

With the implementation of MS, the subsequent biological treatment steps can be reimagined to optimize energy and cost efficiency. The implied alternative involves completely substituting the CAS tank with a configuration comprising zeolite columns (ZC) for ammonium removal and a trickling filter (TF) to remove carbon and excess ammonium. This approach is promising as it provides a cost-effective and energy-saving solution. This substitution can lead to substantial energy savings due to the reduced reliance on aeration. For justification, the following assumptions are valid:

According to Fig. 10, based on work done by Baumann et al. [27], the energy consumption of the CAS process (ECAS) equals 37 kWh cap$^{-1}$ yr$^{-1}$.

For the proposed system, the MS requires an average of 0.1 kWh cap$^{-1}$ yr$^{-1}$, the TF requires 15 kWh cap$^{-1}$ yr$^{-1}$ and the ZC requires 0.1 kWh cap$^{-1}$ yr$^{-1}$.

According to Fig. 11, the energy consumption of the proposed system (EPS) equals 43 kWh cap$^{-1}$ yr$^{-1}$.

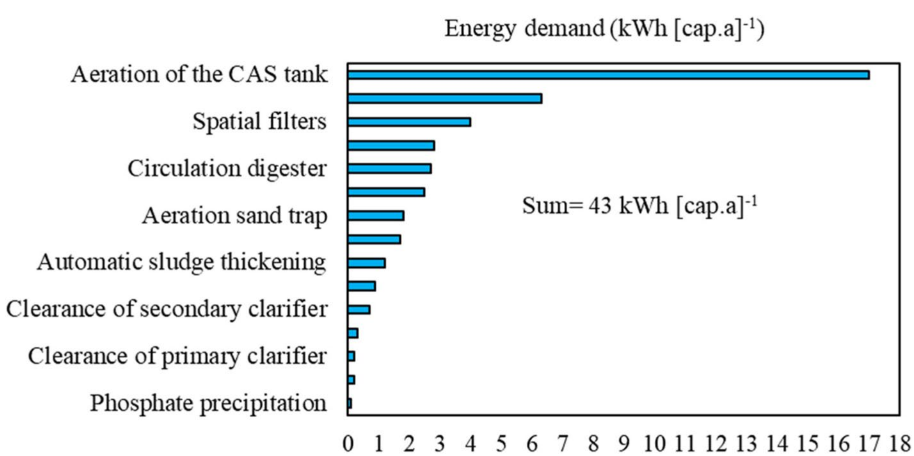


**Fig. 10** Mean consumption values of individual power consumption point for WWTP Büsnau, Stuttgart, according to work done by Baumann et al. [27]

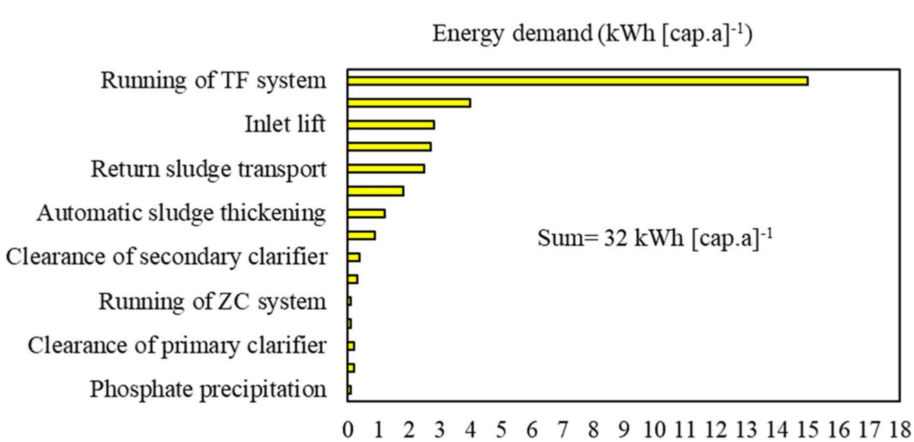


**Fig. 11** Projected mean consumption values of individual power consumption point for Biorefinery Büsnau, Stuttgart, according to work done by Baumann et al. [27]

Therefore, the energy savings per capita = ECAS − EPS= (43–32) kWh $cap^{-1}$ $yr^{-1}$ = 11 kWh $cap^{-1}$ $yr^{-1}$.

A reduction of 11 kWh $cap^{-1}$ $yr^{-1}$ shows a substantial effort to promote energy efficiency and reduce overall energy usage. Such savings can remarkably impact energy consumption and contribute to environmental sustainability when scaled to a larger population. While the exact significance of this reduction may vary depending on the size of the population; however, achieving a 26% decrease in energy consumption per capita can be significant and shows a commitment to sustainable practices.

## 4 Conclusions

This study introduced a new concept for APT based on the increased separation of organic matter from raw wastewater by coupling a PST and an MS. The feasibility of the APT concept is principally possible. However, many technical problems should be overcome. A 20 µm sieve is not solely efficient to be used after PST because of particle breakage due to inertial shear forces produced inside the DS. Flocculants and intermittent BW are recommended to overcome this problem and strengthen the flocs against shear forces. Another solution could be using a finer sieve, also tested in this study. It can enhance solids and COD removal; however, immediate fouling of pores, frequent BW, and not getting concentrated retentate made this option for a long operation difficult. It is expected that by the combination of the flocculation process and a 20 µm in APT system, TSS, COD, and turbidity can be remarkably reduced due to producing much starker flocs which can quickly be detained by MS and are more resistant against shear forces. However, potential problems like frequent BW, observing destabilized flocs in the effluent of MS, and the need for chemical cleaning after prolonged usage are still there. Part of the problems might be solved using larger mesh sizes such as 63 or 100 µm; however, the mesh size should be critically checked and strictly matched with the size of produced flocs during the flocculation process. On the other hand, manufacturers can implement some adjustments on coarser sieves to tackle the shear forces problem: having two rows of waterjets providing a higher surface cleaning area during BW or even using smaller diameter waterjets to render sharp percolation by increased water velocity. The next option could be gentle running of the DS during BW (rotational speed control based). These two improvements might solve the shear forces problem and make it more feasible to have DSs like 20 µm in operation in the APT system. In addition, modifying the BW regime (from hydrostatic pressure-dependent BW to timely adjusted BW) and using an intermediate mesh size sieve, like a 15 m, could be an extra alternative.

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**Authors' contributions**
Behnam Askari Lasaki and Peter Maurer collaborated in the conception of the research. Behnam Askari Lasaki conducted the material preparation, data collection, and analysis. Behnam Askari Lasaki took the initiative in composing the first draft of the manuscript, while Peter Maurer and Harald Schönberger provided feedback on previous versions. All authors have reviewed and authorized the final version of the manuscript.

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**Availability of data and materials**
The datasets used and analyzed during the current study are available from the corresponding author at reasonable request.

## Declarations

**Competing interests**
The authors state that they have no known competing financial interests or personal ties that would appear to have influenced the work disclosed in this study.

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