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Sludge Filtration Installation Design for Wastewater Treatment in Industrial Areas Using Bar Screens, Sedimentation, and Silica Sand Filtration Methods

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Abstract

Wastewater Treatment Plant is an important facility designed to process wastewater from various sources, such as households and industries, before it is discharged into the environment. The main purpose of WWTP is to eliminate or reduce contaminants in wastewater to meet the quality standards set by the government. The treatment process involves the screening stage of solid material, sludge sedimentation, and decomposition of biological or chemical contaminants. One of the main challenges in wastewater treatment is sludge carryover to the processing system, which can reduce pollutant parameters such as Biochemical Oxygen Demand, Chemical Oxygen Demand, Total Suspended Solids and ammonia. This study aims to design a sludge filtration system consisting of bar screening, sedimentation, and filtration unit with a combination of silica sand. The design is outlined in the form of a scientific article to contribute to the development of wastewater treatment studies. The bar screen is used to filter rough solids in the early stages, sedimentation is used to separate heavy particles using gravity, and the filtration unit is designed using a single silica sand filter to reduce TSS. With a processing discharge of 6,300 m^3/day, the resulting design is expected to improve the operational performance of WWTPs, meet the wastewater quality standards according to PerMen LHK No. 16 of 2016, and produce good quality effluent BOD 13,43 mg/L, COD 40,47 mg/L, TSS 1,9 mg/L and ammonia 0,42 mg/L. The results of this planning provide a sustainable and efficient solution for wastewater treatment.

Keywords: damaging pumps, pollutant, quality standards, solid particles, waste stream.

INTRODUCTION

Wastewater Treatment Plants (WWTPs) in industrial areas play a vital role in preventing environmental pollution from liquid waste discharged from industrial and domestic activities. However, in practice, many WWTPs lack adequate pre-filtration systems to handle the suspended solids and sludge carried in the waste stream. Excessive sludge accumulation, often without effective reduction and management strategies, poses environmental challenges and high operational costs (Liu et al., 2022). Sludge buildup before further treatment can damage equipment such as pumps and reduce the overall efficiency of the system. This issue is becoming increasingly urgent because incompletely filtered wastewater risks contaminating open water bodies, damaging ecosystems, and violating wastewater quality regulations (Jan et al., 2022). Another problem with sludge is its high content of heavy metals and pathogens, which limits its use as a sustainable fertiliser without further adequate treatment (Sugurbekova et al., 2023).

The wastewater treatment process includes solids filtration, sedimentation, and decomposition of biological or chemical contaminants from the sludge (Rusmaya et al., 2021). This is intended to eliminate or reduce contaminants in wastewater to meet established water quality standards before discharge into water bodies (Zahmatkesh et al., 2023). Discharge of liquid waste into water bodies without sludge can only be safely carried out after dewatering and stabilisation of the sludge, to ensure that no suspended solid residues contaminate the water body (Vilakazi et al., 2023).

Sludge that escapes into wastewater treatment plants is a serious problem that can compromise the efficiency and effectiveness of the wastewater treatment process (Marutescu et al., 2023). Unstable handling of the resulting sludge can degrade the quality of the resulting liquid waste outlet, as it can lead to an increase in several other pollutant parameters. This complicates the treatment of liquid waste, especially biological waste. Furthermore, liquid pollutants such as ammonia, nitrate, and nitrite can be indicators of the quality of WWTP and water (Qrenawi & Rabah, 2020). This condition results in inefficient treatment for Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), and ammonia.

Based on these issues, sludge filtration is necessary to address these issues. This process involves separating large solids, sedimentation, and finer filtration to improve the quality of the treated wastewater, eliminating large, agglomerated, and small particles (Prabu et al., 2020). The materials and design can reduce these particles.

The first step at the entrance involves the separation of coarse solids, which is achieved by installing a bar screen at the inlet. This fence sorts large materials, preventing them from entering the WWTP (Chen & Engeda, 2021). The sedimentation process is then used to separate particles from the water using gravity, which can be solids that have passed the bar or those with sufficient weight. Sludge, which is a particle heavier than water, can be separated during the sedimentation process (Beshr et al, 2023). The filtration unit is used as a secondary treatment to remove suspended and colloidal residues to maximise effluent quality. The filtration unit uses a single-media sand filter with silica sand to reduce TSS levels. The reduction in TSS levels is due to the filtration process that occurs when wastewater passes through the silica sand filter media. Suspended particles in the wastewater pass through the silica sand, where they are filtered, reducing TSS levels (Choksi et al., 2023).

This study aims to design a sludge filtration installation for the bar screening, sedimentation, and filtration units using a combination of silica sand with a flow rate of 6,300 m^3/day in the Kujang Cikampek industrial area. The design includes calculating the dimensions and equipment requirements for each unit to compare with the existing system based on national wastewater quality standards. The novelty of this research lies in the application of an integrated bar screen-sedimentation-silica sand filtration pretreatment system that is adapted to the characteristics of industrial area liquid waste, in order to increase the efficiency and quality of WWTP effluent.

METHOD

The research method in this project uses a theoretical analytical design approach, with systematic stages starting from problem identification, collecting secondary data on waste characteristics, and then calculating and creating design drawings for the wastewater treatment unit, including bar screens, sedimentation, and silica sand filtration, at the WWTP near the cement factory in the Kujang Cikampek industrial area. Design and calculations are used to ensure each unit functions properly and meets standards.

Design Approach: Staged Linear Flow

Waste moves linearly from upstream to downstream through the following sequence:
bar screen – sedimentation – silica sand filtration. This approach was chosen because it allows for a gradual and efficient reduction in pollutant load through physical and gravity processes, without involving chemical or biological reactions, according to the characteristics of the contaminants at each stage (Kordbacheh & Heidari, 2023). Water pollutants and approaches for their removal. *Materials Chemistry Horizons*, *2*(2), 139-153.. This approach is ideal as a pretreatment or primary treatment system in industrial wastewater treatment before it enters the next stage or is discharged into the environment.

For the bar screen unit, calculations are performed to determine the number of bars required, the spacing between bars to capture specific-sized waste, and the estimated energy loss (head loss) due to water flow through the screen. Design parameters were determined based on waste characteristic data from secondary studies and the SNI 6774:2008 technical guidelines. Validation of the calculation results was carried out by comparing them with existing WWTP designs and reference values from the literature on industrial wastewater filtration unit design. The sedimentation unit was designed using Type II, taking into account residence time and particle settling velocity according to fluid characteristics. Meanwhile, for the silica sand filtration unit, calculations were made for filtration velocity, contact time, media expansion during backwashing, and the type and size of silica sand used as the filter media. Furthermore, filter nozzles were also taken into account to ensure even water flow distribution and optimal filtration performance.

Data analysis was conducted using a descriptive comparative method by comparing the design calculation results to the effluent quality standards stipulated in Ministerial Regulation of the Environment and Forestry No. 16 of 2016. Validation was carried out by reviewing design parameters with reference to technical aspects and the results of previous similar design trials to assess improvements in BOD, COD, and TDS removal efficiency. The calculation results are then compared with the design standards in SNI 6774:2008 to ensure the design complies with applicable quality standards and design principles.

RESULT AND DISCUSSION

Bar Screen Unit

The bar screen unit can filter large solid waste such as plastic, cloth, and coarse organic waste. Particles larger than 20 mm are completely filtered, reducing the potential for clogging and damage to downstream pumps (Zahmatkesh et al., 2023). The bar screen functions to filter waste or large particles in wastewater before it enters the equalisation tank (Sari et al., 2022). The parameters calculated for the bar screen are the number of bars, the spacing between them, and the head loss. The bar screen design criteria used are shown in Table 1.

Table 1. Bar Screen Design Criteria

Parameter	Unit	Value
Flow velocity	m/s	0,3-0,6
Opening distance	mm	25-50
Bar width	mm	4-8
Channel slope	derajat	45-60
Bar spacing	m	0,02-0,075

The selection and calculations related to the bar screen design planning are as follows: Wastewater discharge (Q) is 0.07315 m3/s, flow velocity (v) is 0.6 m/s, bar width (w) is 0.008 m, bar spacing (b) is 0.025 m, and grid shape factor β is 1.79.

Calculation of the effective cross-sectional area or Across on the bar screen that is passed by wastewater can be calculated using Equation (1) where Q is wastewater discharge (m3/s), v is flow velocity (m/), D is channel diameter (m), and L is channel length (m).

Across $= D \times L = \frac{Q}{v}$ (1)

$= \frac{0.07315\ m^2/s}{0,6\ m/s}$

$= 0.1219\ m^2$

Determine the diameter of the channel

D $= \sqrt{\frac{Across}{2}}$

$= \sqrt{\frac{0,1219\ \text{m2}}{2}}$

$= 0.2468$ m

The number of filter rods or gratings (n) can be calculated using Equation (2), where L is the total channel width (m), w is gap between rods (m), and b is the rod width (m).

L (width of channel) = n x w + (n+1) b (2)

1 m = (n x 0.008) + (n + 1) 0.025 m

n = 29.5 or 30 gratings

Control the distance between the roads according to Equation (3).

1 m = (30 x 0.025 m) + (30 + 1) b (3)

1 m = 0.24 + 31b

b + 0,025 m

Calculate the width of the screen opening (Ls) using Equation (4).

Ls = (n + 1) b (4)

Ls = (30 + 1) 0.025

= 0.7595 m

Calculate the submerged screen length (Ps) using Equation (5).

Ps $= \frac{D}{Sin\ 45°}$ (5)

Ps $= \frac{0.2468}{Sin\ 45°}$

= 0.29 m

Calculation of the cross-sectional area of the screen through which water passes (As) according to Equation (6).

As = Ps x Ls (6)

As = 0.29 m x 0.7595 m

$= 0.2202\ m^2$

The flow velocity on the screen can be calculated using Equation (7).

v $= \frac{Q}{A}$ (7)

$= \frac{0.07315\ m^3/s}{0.2202\ m^2}$

= 0.3321 m/s

Acceptable flow velocity is > 0.3 m/s.

The pressure loss on the screen (hL) can be calculated using Equation (8), where β is the lattice shape factor, g is gravitational acceleration (m/s2), θ is angle of inclination of the screen bar.

hL $= \beta \left(\frac{w}{b}\right)^{4/3} \frac{v^2}{2g} \sin\theta$ (8)

hL $= 1.79 \left(\frac{0.008\ m}{0.025\ m}\right)^{4/3} \frac{0.3321^2}{29.81\ m/s^2} \sin 45$

= 0.00187 m

Based on the calculation results, the number of bars is 30, the distance between bars is 0.025 m, and the head loss on the screen is 0.00187 m. This configuration balances the need to open a large enough cross-section to ensure unimpeded flow (flow velocity on the screen ≈ 0.33 m/s) while effectively retaining coarse particles (>20 mm). However, the relatively small distance between the bars can increase pressure loss due to greater resistance to fluid flow when passing through narrow spaces (Dvorský et al., 2020). This can make the screen susceptible to clogging if not accompanied by an adequate cleaning strategy. Therefore, design choices need to balance the ability to filter solids with ease of cleaning. The bar screen design is shown in Figure 1.

Sedimentation Unit

The sedimentation process is effective in reducing water turbidity and organic load before the filtration stage. Sedimentation is the settling of particles. The planned sedimentation unit is Type II, with the sedimentation tank design criteria based on SNI 6774 of 2008. The calculations related to the sedimentation unit design are as follows:

Design Criteria:

Sedimentation tank shape	= Rectangular
Residence time	= 1.5-2.5 hours
Overflow Rate (OFR)	= 0.8-2.5 m3/s
Weir Loading rate (WLR)	= <11 m3/m²/day
P:L ratio	= 2-6:1

Planned:

Designated discharge	= 0.07315 m3/s
OFR	= 1 m3/m²/day
Number of tanks	= 1
P:L ratio	= 2:1
Residence time	= 7,200 s
Freeboard	= 20% H

Planning Results

Sedimentation Zone

A surface	= 175.2 m²
Width, length	= 9.5 m; 19 m
Volume	= 622.725 m3
Total depth	= 3.6 m.

Check Reynolds number and Frandre number

Vh = 2.56×10^{-3}

V scouring = 0.035 m/s

V scouring > Vh, so no scouring will occur

Nre = 5,856,256 (not met, Nre < 2000)

Nfr = 4.72×10^{-4}

(met requirement > 10^{-5})

The Reynolds number is not met because the Froude number is already met. This is because the two numbers have comparable values.

Baffle Design

The baffle is placed 1.5 m in front of the inlet pipe.

Baffle length = 9.5 m

Baffle height = 3.6 m

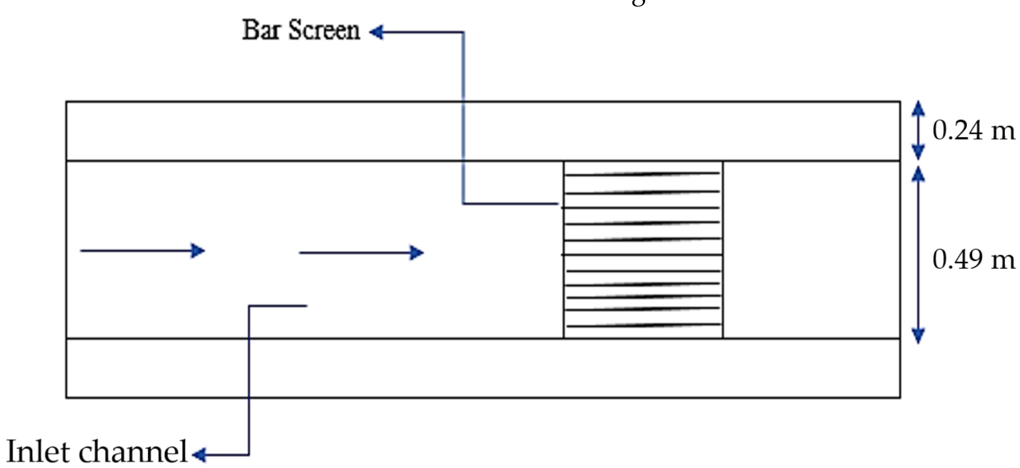


Figure 1. Intake Duct and Bar Screen Design

Sludge Zone

The sludge zone is planned to be a truncated pyramid.

Depth = 1.83 m

Surface area (A1) = 66.2 m^2

Surface area (A2) = 30 m^2

Sludge chamber volume= 86.09 m^3

Outlet Zone

The spillway on the gutter is planned to be a serrated weir (V-notch), angled at 45°.

Weir length = 18.25 m

V-notch width = 0.1 m

Number of V-notches = 61

V-notch height = 0.074 m

Number of gutters = 2

Length, width = 9.12 m; 0.6 m

Depth = 3.45 m

Type II sedimentation system with dimensions of 19 m x 9.5 m x 3.6 m creates an adequate settling zone for a discharge of 6,300 m3/day. A length-to-width ratio of 2:1 supports stable laminar flow. However, operationally, this system requires periodic sludge dewatering to prevent excessive sedimentation, which can reduce efficiency. Compared with the study by Rusmaya et al. (2021) 2-hour residence time is considered moderate for industries with high organic loads. In field implementation, desludging frequency should be determined based on observations of sludge accumulation rate and planned sludge disposal schedules. The design of a rectangular sedimentation unit is shown in Figure 2.

Filtration Unit

The filtration unit is a continuation of the sedimentation process, where particles that fail to settle during the sedimentation process are filtered using porous media (Bârjoveanu et al., 2019). The porous media used in filtration units typically consists of sand, gravel, or other special materials designed to capture particles of a specific size (Choi et al., 2023).

The use of silica sand as a filtration medium in wastewater treatment is more effective than other media. This is because silica sand has uniform particle sizes and a high level of porosity, making it capable of filtering sludge, microorganisms, solid particles, and coagulated flocs in industrial wastewater. Compared with other filter media, such as manganese sand, silica sand is more effective because it is more commonly used in filtering contaminants than manganese sand, which is specifically used to remove iron and manganese. Furthermore, silica sand is environmentally friendly because it is a natural material that does not react with contaminants and can be reused, reducing operational costs. Research by Zahrina & Yenie (2022) found that using silica sand as a filtration medium effectively neutralizes acidic pH in wastewater, reduces turbidity, and lowers BOD values.

The filtration method used is a single-media rapid sand filter (Nikookar, 2023). The design used in the filtration unit planning is as shown in Table 2.

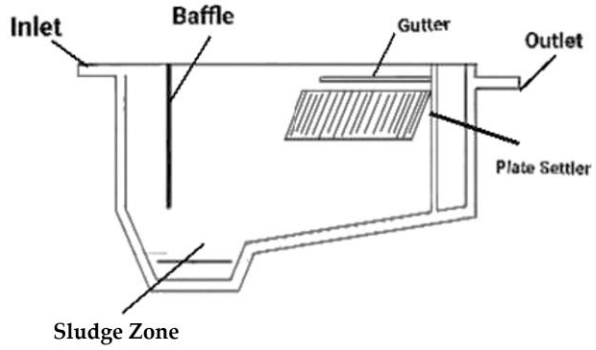


Figure 2. Sedimentation Unit Design

Table 2. Filtration Unit Design Criteria

Parameter	Unit	Value

Filtration speed	m/hour	6-11
Washing time	minutes	10-15
Expansion	%	30-50
Sand Media	mm	
➢ Thick		300-700
➢ Single media		600-700
➢ Double media		300-600
➢ Effective size		0.3-0.7
➢ Uniformity coefficient		1.2-1.8
➢ Porosity		0.4
Gravel Media		
➢ Think	mm	100-600
➢ Effective size	mm	5-20
➢ Uniformity coefficient		2-3
➢ Porosity		0.3-0.5
Filter Nozzle		
➢ Nozzle slot width	mm	<0.5
➢ Percentage of nozzle slot area	%	>4

Calculations related to the filtration unit design planning are as follows:

Treatment capacity = 1.75 m^3/s

Operating time = 24 hours/day

Filtration velocity (vf) = 0.00167 m/s

P:L ratio = 1:1

Freeboard = 0.3 m

The media planning is shown in Table 3:

Fluid viscosity (μ) = 0.001

Fluid velocity (ω) = 1000 kg/m^3

Head loss (hL) of the total media

a) Silica sand media, with Nre calculated as the Reynolds number and Cd as shown in Equations (9), (10), and (11).

$$Nre = \frac{\omega . d . vf}{\mu} \quad (9)$$

= 1.336

$$Cd = \frac{24}{Nre} + \frac{24}{\sqrt{Nre}} + 0.34 \quad (10)$$

= 20.9

$$HL = 1.067 \frac{Cd . L . Vf^2}{\omega . d . \varepsilon^4 . g} \quad (11)$$

= 0.12 m

b) Buffer media (gravel)

Nre = 2.42

Cd = 12.18

HL = 0.013

So, total media *head loss*:

= $h_{L(pasir)} + h_{L(kerikil)}$

= 0,12 + 0,013

= 0,133 m = 13,3 cm

Table 3. Media Design Criteria

Parameter	Silica Sand Media	Buffer Media (Gravel)
Thick	40 cm	10 cm
Grain size	0,5-1,1 mm	0,3-0,26 m
Porosity (ε)	0,4	0,38
Shape factor (Ψ)	0,8	0,7
Specific gravity	2,65 kg/m^3	2,65 kg/m^3
Gravity (g)	9,81 m/s^2	9,81 m/s^2

Total Expansion

a) Silica sand media, with Nre calculated as the Reynolds number and Cd as shown in Equations (12), (13), (14), and (15).

$$Vs = \sqrt{\frac{4 . g \, (sg-1) . d}{3 \, Cd}} \quad (12)$$

= 0.6 m/s

$$Vb = Vs . \varepsilon^{4,5} \quad (13)$$

= 0.0097 m/s

$$\varepsilon e = \left[\frac{Vb}{Vs}\right]^{0,22} = 0,4$$

$$\frac{X}{(1-\varepsilon e)} = 1.68 \quad (14)$$

$$\text{expansion height} = (1-\varepsilon)L \, \Sigma \frac{X}{(1-\varepsilon e)} = 0,5 \text{ m} \quad (15)$$

b) Buffer media (gravel)

Vs = 0.62 m/s

Vb = 0.0079 m/s

εe = 0.38

$\frac{X}{(1-\varepsilon e)}$ = 1.62

expansion height = 0.1 m

So, Total expansion = 0,5 + 0,1 = 0,6 m

Total *Head loss*:

a) $H_{f \, (Pasir)} = (sg-1)(1-\varepsilon)L$ (16)

= 0,39 m

b) $H_{f \, (kerikil)} = (sg-1)(1-\varepsilon)L$

= 0,1 m

c) $H_{f \, total}$ = 0,39 m + 0,1 m = 0,49 m

Filter tank height:

= $H_{f \, total}$ + *freeboard* (17)

= 0,49 + 0,3 = 0,79 m

= 0,8 m

B*ackwash*:

- V *backwash* = 0,0081 m/s
- Periode = 1 kali
- Q *backwash* = Vb x A Filtration (18)
  = 0,0081 m/s x (1x1) m
  = 0,0081 m^3/s
- Pump head requirements = 0,6 m
  Underdrain system using nozzle
- *Slot nozzel* = 1,2 mm
- Height *slot* = 15 mm
- Need *nozzel* = 22 buah

Zona *Outlet*

- Total *gutter* = 5 buah
- Length *gutter* = panjang filter (1 m)
- Width *gutter* = 0,03 m
- Depth *gutter* = 15 cm
- Height location *gutter*

= H ekspansi + *Freeboard*

= 0,6 m + 0,3 m = 0,9 m

A vertical filtration unit design used in industrial wastewater treatment systems, with filter media consisting of silica sand and gravel. Wastewater enters through a filtration inlet pipe at the top and flows downward by gravity through a 40 cm thick layer of silica sand and 10 cm thick gravel. The silica sand layer serves to filter fine particles, while the gravel supports the sand layer and filters larger particles. Clean water is then collected through a nozzle at the base of the unit and exits through the filtration outlet pipe. To maintain filtration efficiency, this system is equipped with a backwash process, which is backwashing the filter media using clean water that flows through the backwash inlet pipe and is released through the backwash outlet pipe. This process aims to remove dirt that has accumulated in the filter media, so that the unit can function optimally in the long term. This design is effective in reducing turbidity and suspended solids before wastewater is discharged into the environment, as shown in Figure 3. is a filtration with a single media rapid sand filter type.

The use of silica sand as a filtration medium effectively reduces BOD, COD, TSS, and ammonia levels in wastewater. Filtration efficiency shows significant results, with a reduction in BOD of 42%, COD of 29%, TSS of 90%, and ammonia of 86% (Dos Santos & Daniel, 2020). However, the risk of long-term performance degradation due to fouling, clogging, biofilm, or mineral scale must be anticipated through frequent backwashing and head loss monitoring. Comparative data on BOD, COD, TSS, and ammonia values at the old and new design outlets are shown in Table 4 and Table 5.

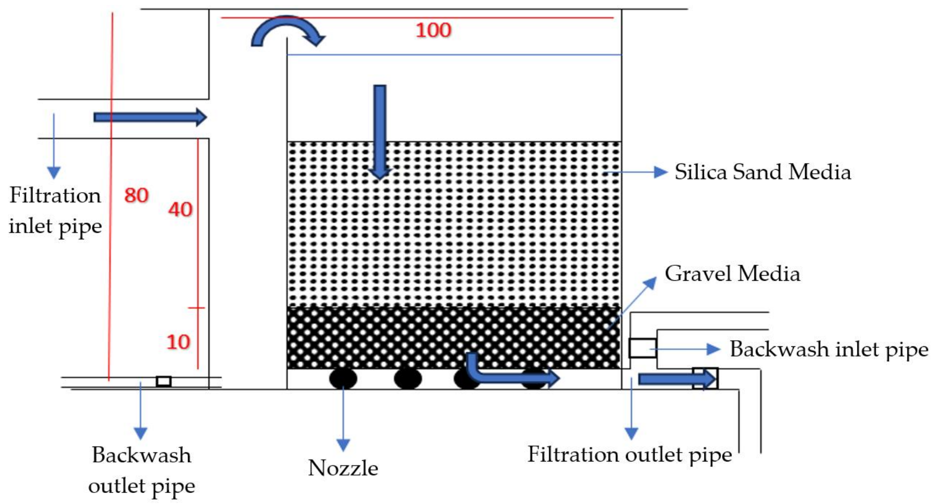


Figure 3. Filtration Unit Design

Table 4. Comparison of BOD, COD, and TSS values based on waste quality standards according to the Minister of Environment and Forestry Regulation No. 16 of 2016

Parameter	Value outlet old design	Value outlet new design	Standard
BOD	23 mg/L	13,34 mg/L	30 mg/L
COD	57 mg/L	40,47 mg/L	100 mg/L
TSS	19 mg/L	1,9 mg/L	30 mg/L
Amonia	3 mg/L	0,42 mg/L	10 mg/L

Comparison Design of Wastewater Treatment Plant Designs

Before Adding Additional Units: The inlet goes directly to the equalization tank (2) without pre-filtration. There is no pre-filtering unit for coarse particles (bar screen), allowing large materials to enter the system and potentially damage the pump. After the neutralization tank (3), the water is immediately processed in the Sequencing Batch Reactor (SBR) (4), without settling or filtration of large particles. The outlet goes directly to the outlet control tank (5) and then to the sparing system (6) and is discharged to the environment.

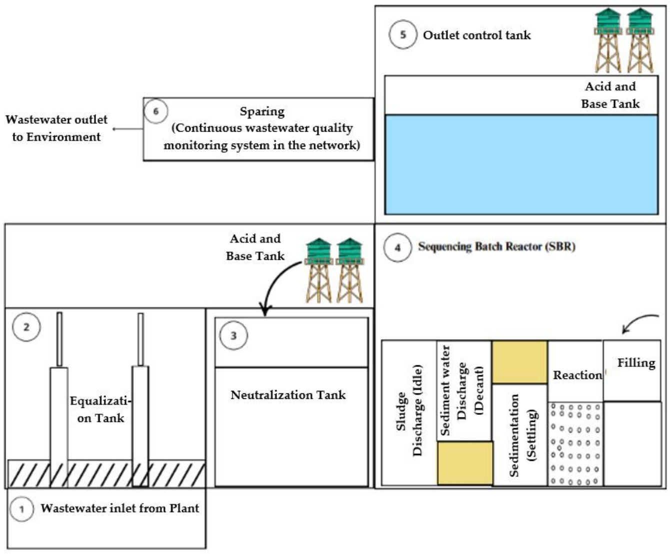
After Adding Additional Units: A bar screen is added in front of the equalization tank (2) to filter coarse debris such as plastic and rags from the wastewater. After the neutralization tank (3), the water flows first to the sedimentation tank (4). Here, large suspended particles settle to the bottom (sludge zone), increasing the efficiency of the organic load entering the SBR. From the sedimentation tank, water flows to the silica sand filtration unit (5), which consists of silica sand and gravel media, to remove fine particles and improve water clarity. The water then enters the SBR unit (6) for biological treatment. The system ends at the outlet control tank (7) and is monitored by the sparing system (8) before being discharged into the environment.

A comparison of the WWTP designs before and after the addition of the units is shown in Figure 4. This integrated treatment system combines physical, chemical, and biological processes—including screening, equalization, pH control, sedimentation, sand filtration, and SBR—to ensure the wastewater meets discharge regulations and minimizes environmental impact. The development of advanced pre-treatment technologies, hybrid desalination systems, and zero liquid discharge approaches aligns (Poirier et al., 2023) with the concept of sludge filtration installation design using bar screens, sedimentation, and silica sand filtration methods for industrial wastewater treatment, as both aim to optimize water management, minimize pollutants, and enhance the sustainability of treatment processes.

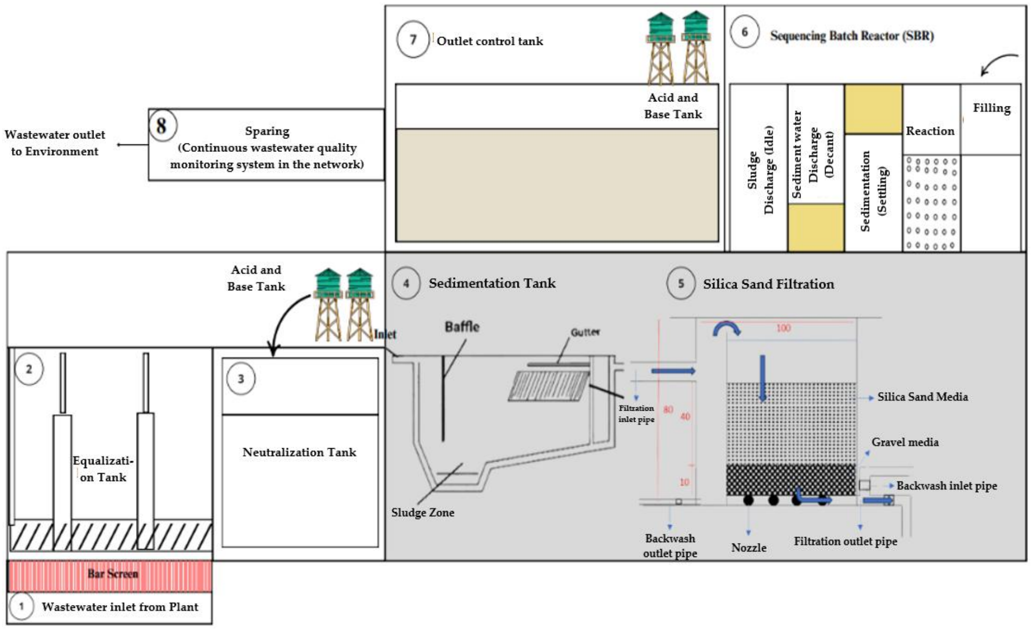
Table 5. Comparison of Filtering Aspects, Efficiency and Quality

Aspects	Old Design	New Design
Initial filtration	None	Present (Bar Screen)
Initial settling	None	Present (Sedimentation Tank)
Filtration	None	Present (Silica Sand Filtration Unit)
Pump protection efficiencty	Low	High
Final effluent quality	Not optimal	Less than optimal Clearer,

meets quality standards



(a)



(b)

Figure 4. WWTP design (a) Before and (b) after the addition of Bar Screen, Sedimentation and Filtration Unit

The development of advanced pre-treatment technologies, hybrid desalination systems, and zero liquid discharge

CONCLUSION

The design of the sludge filtration system at the Kujang Cikampek Industrial Area Wastewater Treatment Plant has successfully produced an effective technical design in reducing the main pollutant parameters, namely BOD, COD, and TDS, in order to meet wastewater quality standards and minimize environmental impacts. The bar screen unit is designed with 30 bars, a bar spacing of 0.025 m, and a head loss of 0.00187 m. This component functions to filter large particles initially so that the organic and solid loads that contribute to BOD and COD can be reduced before entering the next stage. Furthermore, a rectangular sedimentation unit with dimensions of 19 m x 9.5 m x 3.6 m is designed to efficiently settle suspended particles, helping to reduce TSS which is correlated with BOD and COD parameters. The square-sized silica sand filtration unit with a height of 0.8 m and a length-to-width ratio of 1:1 plays an important role in removing fine particles and residual dissolved compounds, thus contributing to a decrease in TDS values. This system is equipped with 22 nozzles and a backwash discharge of 0.0081 m^3/s, as well as a 0.9 m high gutter to support flow efficiency. Based on the calculation results, this design is capable of processing wastewater with a discharge of 6,300 m^3/day. This system shows an increase in the operational performance of the WWTP, meets the water quality standards according to the Regulation of the Minister of Environment and Forestry Number 16 of 2016, and produces good quality effluent with BOD parameters of 13.34 mg/L, COD 40.47 mg/L, TSS 1.9 mg/L, and ammonia 0.42 mg/L. This design not only improves the operational efficiency of the WWTP but also introduces a pretreatment approach based on a combination of bar screen-sedimentation-silica sand filtration that is specific to the needs of industrial areas. This concept has the potential to be applied to similar WWTPs in other industrial areas to reduce the pollutant load from the start of treatment. Further research can be focused on testing system performance in the field, evaluating operational costs, and integrating filtration units with biological processes to achieve more optimal and sustainable treatment efficiency.

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