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Design and Different Sections of a Waste Water Treatment Plant

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ABSTRACT:

Water treatment plants are crucial in guaranteeing the availability of safe and drinkable water, which is an essential requirement for maintaining life and promoting societal progress. This study paper explores the complex terrain of water treatment plants, analyzing their architecture, operating strategies, and incorporation of cutting-edge technologies. The main emphasis is on improving efficiency, sustainability, and quality control inside these facilities.

This paper conducts a thorough examination of current literature and case studies to emphasize the difficulties encountered by conventional water treatment technologies and investigates modern solutions and progressions. This study investigates the implementation of state-of-the-art technologies, including membrane filtration, sophisticated oxidation processes, and smart monitoring systems, to enhance the effectiveness of treatment, reduce the environmental footprint, and maximize the use of resources.
The purpose of this study is to contribute to the development of strategies for water treatment plants, promoting sustainable practices that consider ecological sensitivity, operational efficiency, and societal needs. This article provides a thorough and extensive source of information for policymakers, engineers, environmentalists, and stakeholders who are working towards the development of water treatment technology and the establishment of a sustainable water future for future generations.

Keywords: **Water Treatment Plants, Architecture, Environment, Technology**

INTRODUCTION:

Wastewater treatment facilities are essential for water purification, eliminating contaminants like waste, grease, oils, and debris. The processes include settling to separate particles and biodegradation to decompose organic materials, ensuring the released water meets environmental safety standards.
Preliminary treatment: encompasses the removal of large solids (such as bottles, fabric, and plastics) from water utilizing bar racks and screens.
Primary treatment involves physio-chemical processes to settle and precipitate suspended solids, reducing the biochemical oxygen demand of organic solids. This treatment neutralizes water, eliminates volatile contaminants, and removes greases and oils.
Secondary treatment comprises biological processes that diminish the organic matter in wastewater. This includes aerobic processes, degrading organic material with oxygen, and anaerobic processes, oxidizing organic matter without oxygen, followed by secondary settling.

REQUIREMENT
150MLD= 15 x 10^7 lit = 15x10^4
cu-m Population= 694444 Average daily
Demand=83333333 lit
Maximum Daily demand=149999999≈150
million lit/day
Discharge=1.73cu-m/sec

SCREENING

Screening stands as the initial unit operation in wastewater treatment plants (WWTPs), designed to eliminate objects like rags, paper, plastics, and metals. This prevents damage and clogging of downstream equipment, piping, and appurtenances. Some advanced WWTPs utilize both coarse screens and fine screens. Figure 1 illustrates a typical bar screen, which is a form of coarse screen**.** The screening process in wastewater treatment refers to the method of removing large solid objects and debris from the wastewater before it undergoes further treatment.

Water screening is an essential aspect of both municipal and industrial wastewater treatment plants since it effectively captures and retains particles present in the wastewater. At the beginning of the water treatment process, it is imperative to eliminate these solid substances as they might hinder the overall efficiency of the system, cause harm to valuable and essential water treatment machinery, or contaminate the water, resulting in significant disruptions to the entire ecosystem of a region.

Coarse Screen:

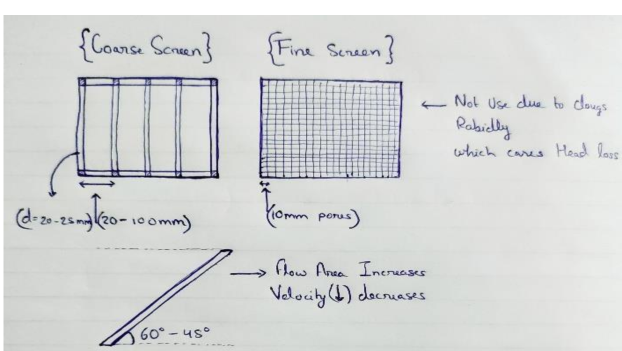
Coarse screens remove large solids, rags, and debris Coarse screens remove large solids, rags, and debris

From wastewater, and typically have openings of 20mm or Larger. Types of coarse screens

Include mechanically and manually cleaned bar

Fine Screen:

Fine screens are typically used to remove material That May Create operation and maintenance Problems in downstream



Processes, particularly in systems that lack primary treatment. Typical opening size for fine screens are 6mm to 10mm

That may create operation and maintenance problems and even if requires it is allowed to place very fine screen with openings of 0.2 to 1.5mm

Level of filtration in the process of treating

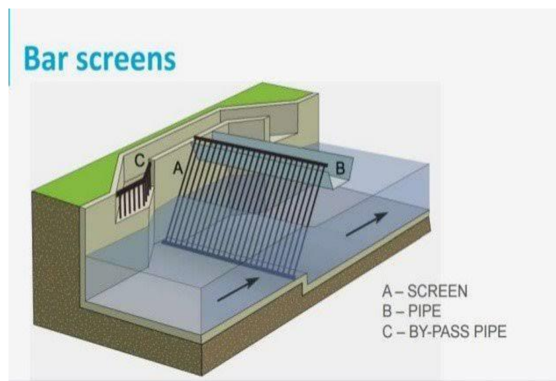
Design taken= Course Screen of 2×2 cross-section Area

Diameter of bars=25mm=0.025m

Distance of bars from Centre to Centre= 60mm=0.06m

Area of screen =4m^2

(Length=2m, width= 2m) Angle of screen= 50°



COAGULATION & FLOCCULATION

Coagulation and flocculation are essential processes used in the treatment of wastewater. Coagulation involves the addition of chemicals to destabilize and aggregate suspended particles, while flocculation promotes the formation of larger particles called flocs.

These processes aid in the removal of impurities and contaminants from wastewater, making it cleaner and safer for disposal or reuse.

Both groundwater and surface water contain dissolved and suspended particles. Coagulation and flocculation are employed to segregate the suspended solids from the water. The characteristics of suspended particles, such as their source, charge, particle size, shape, and density, can vary. These parameters impact the appropriate implementation of coagulation and flocculation. Waterborne particulates possess a detrimental electrical charge, and due to their same surface charge, they exhibit mutual repulsion upon contact. If adequate coagulation and flocculation methods are not employed, suspended solids will persist in the water without aggregating and settling.

COAGULATION TANK

The process of coagulation and flocculation occurs in sequential stages, facilitating the collision of particles and the subsequent formation of flocs. Sedimentation occurs subsequently. Failure to complete the coagulation stage will result in a failed flocculation step, and failure to complete the flocculation step will result in an unsuccessful sedimentation step.

Coagulation is the initial stage of chemical wastewater treatment. The majority of us acquired knowledge about coagulation during our anatomy class. Hematopoiesis occurs when our blood undergoes oxygenation, leading to the formation of a scab or a blood clot. This also applies to the process of treating wastewater.

Coagulation treatment employs a benign substance, such alum, to induce a positive charge in all particles, resulting in their aggregation and facilitating filtration. Coagulation is highly efficient in eliminating chemical phosphorus from water. However, coagulation water treatment is not a new or innovative technology. Excessive mixing does not impact coagulation, whereas insufficient mixing results in an incomplete completion of this stage. The contact period in the rapid-mix chamber generally ranges from 1 to 3 minutes.

Mixing Basin Design (Coagulation)/Rapid mixing-

(According to IS Code-7090-1985)

150MLD – capacity

divided in 2 sections 75MLD

75 x 10^6 lit= 75x 10^3 cu-m

= 75 x 10^3/24 x 60 = 52.083≈ 53 cu-m/ min

= 0.868 Cu-m/sec

Type- mechanical mixer(IS 7090-1985)

Impellers type- propeller mixer(IS 7090-1985)

Impeller material(propeller type)- vane shall me made up of Mild steel confirming to(IS 1730 Part 1 : 1974)

And propeller should made up of cast steel (IS 2644: 1979)

Shaft material (propeller type)- it should be made up of cast iron above the Grade 20(IS 210-1978)

Shaft bearing- The bearing should be suitable for work under water and under suspensions conditions

Motor- for Propeller type mixer the motor shall be totally enclosed fan cooled type(IS 325:1978)

Discharge (Q) = 0.86 cu-m/ sec

Detention time = 60 sec (20 sec – 60sec Recommended for mechanical type IS 7090: 1985)

RPM= 110 (100-120 RPM recommend)

IS 7090-(1985) Recommendations for Design of coagulation Tank

Design Standard Parameter	Design Standard
Velocity Gradient, G	$600^{s-1} \rightarrow 1000^{s-1}$
Tank Volumes, V_T	$< 8.0\ m^3$
Liquid Depth/Tank Width	1.1→1.6
Impeller Diameter/Tank Width	0.3-0.5
Baffle Width	10% Tank Width

Geometrical Design of Coagulation Tank(Rapid mixing)

Maximum volumes recommend (8 m^3) (IS 7090-1985)

Taking per tank volume= 8 m^3(IS 7090 Recommend max. Volume of Tank should be 8m^3)

53/8= 6.62, taking Freeboard minimum 400mm (0.2-06 recommended)

= 7 tank required for 8m^3 capacity

Width of Rectangular tank = 1.5 m (1.1-1.6 Recommended)

Length= 1.5 m(Generally Equal to its width)

Depth= 8/(1.5x1.5)= 3.55 m

Buffle width= 10% of its width if Horizontally placed (both side)or 10% less from Tank Depth Vertically only from the side of input

Taking buffle wall 10% less from Tank Depth Vertically at the side of input

Diameter of impellers = 0.4 m (0.3 to 0.5 Recommended)

Velocity Gradient = 300 for 60 sec Detention Time(IS 7096-1985) for 25° to 30° C

Power(P)= 1.2 watt/m^3/min for given velocity Gradient(IS 7096-1985)

so, for 1hr Treatment= 72 watt/m^3 energy Requires,

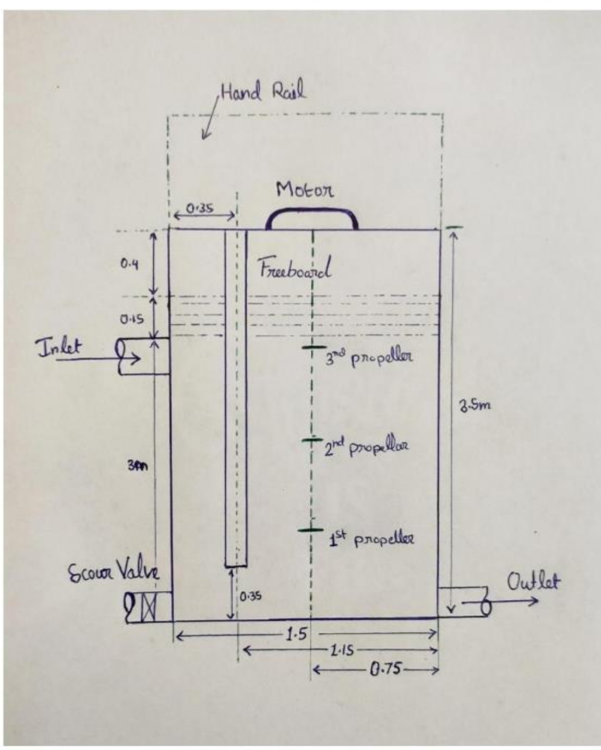
so energy required for 1 Coagulation tank/ hr= 8 x 72= 576 watt(8cu-m capacity)

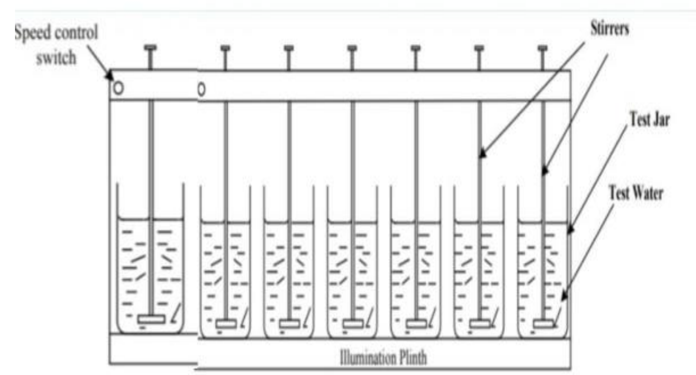
so, to Find Absolutely viscosity(Ú) of Raw water = Ú=P/G'^2 (by Velocity Gradient formula G'=√P/Ú)

U'= 0.0008

U'= V x ù {V= volume of Treatment; u= density of Raw water at 25 to 35°F(900kg/cu-m to 1100kg/cu-m)}

Geometrical Design of Coagulation Tank(Rapid mixing)





7 Rapid mixing tank for Coagulation each one is having a 8 cu-m capacity

FLOCCULATION TANK

Flocculation and coagulation operate together in the process of wastewater treatment. Following the process of coagulation, which causes the waste particles to clump together, flocculating agents are employed in wastewater treatment to eliminate these clumps. Flocculants are polymers that induce the aggregation and precipitation of destabilized particle clusters, effectively eliminating them from the filtered water. They can have varying degrees of weight, ranging from lightweight to medium weight, or high weight. The weight employed is contingent upon the nature of the particle.

The design intervals for flocculation range from 15 to 20 minutes up to an hour or longer. It is crucial to closely monitor the mixing velocity and mix energy. When the size of floc rises, the velocity and energy of mixing are usually decreased in order to avoid the floc from being torn apart or sheared. Once flocs are disintegrated, it becomes challenging to reassemble them to their ideal dimensions and durability. The operator's level of control in flocculation is greatly influenced by the equipment's type and design.

Design of Slow Mixing Basin(Flocculation tank)

(According to IS-7208:1992, Guidelines for Flocculation tank)

150MLD

2 Tank of 75MLD= 75x 10^6 lit= 75x10^3 cu-m

Detention Time 30 min (10 min to 30 min, IS 7208:1992 Recommendation)

Volume of Tank= (75 x 10^3 cu-m /24)/(1/2)= 1562cu-m≈1600(40 cu-m Freeboard)

Depth=8m(IS-7208:992 Doesn't recommend the Depth of Tank)

Pressure=70632 Pa {Pressure at 8m depth (P=pxgxh ; where p=Density,g=Gravity,h=height)

p=900kg/m^3 of Raw water Taken, Gravity=9.81, height= 8m}

Length of Tank= 20m

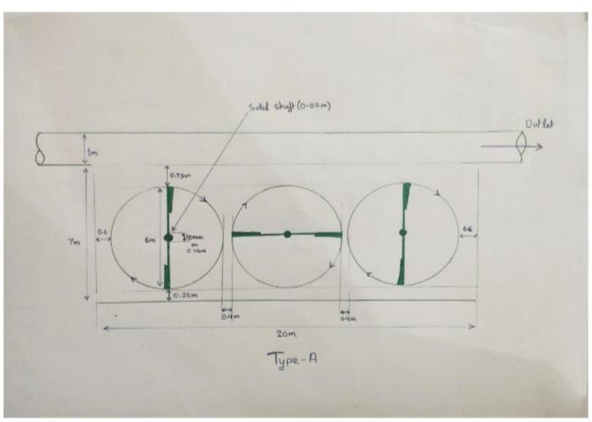
Width of Tank= 10m

Type- mechanical Flocculation by using paddle (IS 7208:1192 Says, Its a most Generally method adopted in india)

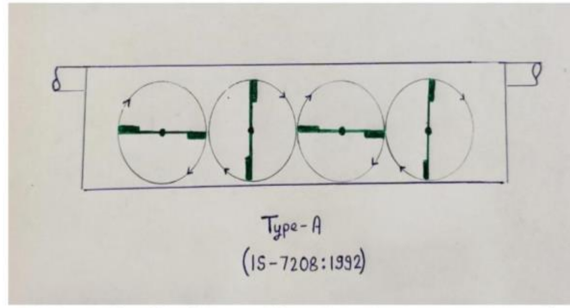
Paddle Type- Type A(IS 7208:1992; it consists of a series of paddles placed transversely across the tank width)

consumption(P)= 2{by using formula of Velocity Gradient ;G'=√(P/Ú)}

Velocity Gradient=50 sec^-1(IS 7208:1992 Recommend 30-60 sec^-1)



Geometrical Design of Slow Mixing basin(Flocculation Tank)



Thickness of Paddles (6 mm, mild steel , confirming to IS 226:1975)

Motor- The motor should be totally enclosed and fan cooled type manufacture.

RPM- 3 (IS 7208:1992 recommend 2 to 3)

Solid shaft Diameter- 0.05m(IS 7208:1992)

Paddle Diameter= 6m

Distance between paddle to paddle =0.4m(IS 7208:1992 Recommend 0.25m-0.4m)

Distance between paddle to floor= 0.25m(IS 7208:1992 recommend 0.15 to 0.3)

Distance between paddle to side wall= 0.6(IS 7208:1992 Recommend for 30 min IS 7208:1992)

Absolute viscosity (Ú)= 0.0008

SEDIMENTATION TANK

A sedimentation tank, also known as a settling tank or clarifier, is an integral part of a contemporary water supply or wastewater treatment system. A sedimentation tank facilitates the separation of suspended particles in water or wastewater by allowing them to settle down while the liquid passes through the tank at a slow pace, resulting in a certain degree of filtration. Sludge, a layer of accumulated solids, accumulates at the bottom of the tank and is subsequently removed. Prior to sedimentation in drinking-water treatment, coagulants are introduced into the water to facilitate the settling process, which is subsequently followed by filtration and other treatment procedures.

Assuming The maximum Daily Demand as 1.8 times the Average Daily Demand(ISC 1.4-1.8)

The maximum Daily consumption= Average Daily Demand x 120 x 1.8

Average daily Demand= population x Per capita demand

Average Daily Demand= 694444 x 120 = 83333333 lit

Maximum Daily Demand= 83333333 x 1.8= 149999999 ≈ 150 million lit

Dividing this in 2 section of Tank = 150 million lit/2= 75million lit

Design of per 75 MLD(million litres Daily)

Quantity of water used to Treat during the Detention time of 4hr(usually take 2-4 hr max)

(75x10^6)/24x 4= 12.5 x 10^6 lit = 12.5 x 10^3 Cu-m

So, The capacity of Tank is = 12.5 x 10^3 cu-m

Assuming overflow Rate is 1000 lit/hr/m^2 (1000 to 1250 is the maximum allowable rate)

Q/B x L = 1000 (where Q= Discharge, B= width, L= Length)

So, B x L = Q/1000

Where Q= capacity/Detention time = (12.5 x 10^6 / 4) Lit/hr

Q= 3125 x 10^3 lit/hr

Plane Area= B x L= Q/1000 = 3125x 10^3/1000 = 3125 m^2

Using width of the Tank as 25m

Let the measuring width is 25m then , Length of Tank is (3125m/25m)= 125 m

In order to enhance the effectiveness of purification, it is necessary to supplement primary sedimentation with a secondary treatment method such as a trickling filter or activated sludge in contemporary sewage treatment processes. Prior to sedimentation, the typical procedure involves the use of bar screens and grit chambers to remove large objects and coarse solids.

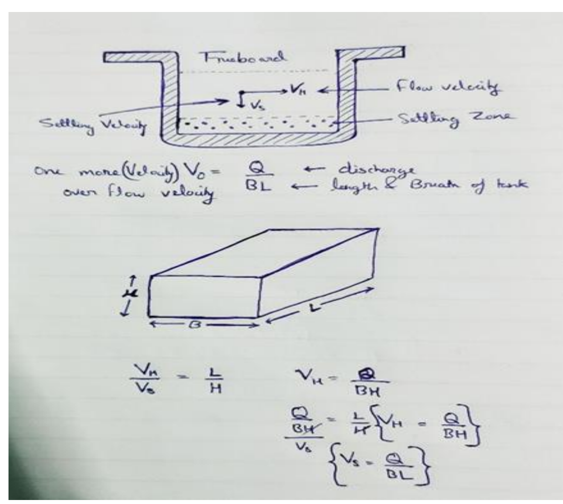
Depth of the tank is 4m then the 12.5 x 10^3 cu-m/4= 3125 Providing Extra Depth for sludge storage says (use 0.5 in 4m) so for 4m depth it is
0.5 m extra Depth
Total Depth= 4.5 at the starting End,
And 4.5+(125/50) = 7m at d/s End (by using a slop; 1 in 50) {i e 1 in 40 to 1 in 60 acceptable} and Using Free Board of 0.8 m (because for every 5 to 6 m depth 0.5 Free Board Recommended) from the water level

Sedimentation Tank Design Calculation

1. Rectangular Tanks: Rectangular tanks possess a planar shape with numerous baffle walls. The primary purpose of the baffle wall is to inhibit short-circuiting and diminish the speed of incoming water, therefore elongating the particle's effective travel distance. This sedimentation tank typically features a channel-type inlet and outflow that span the whole width. The floor between two baffles is designed to resemble a hopper, descending towards the center where a sludge pipe is installed.

2. Circular Tanks: There are two categories of circular sedimentation tanks based on the water flow:

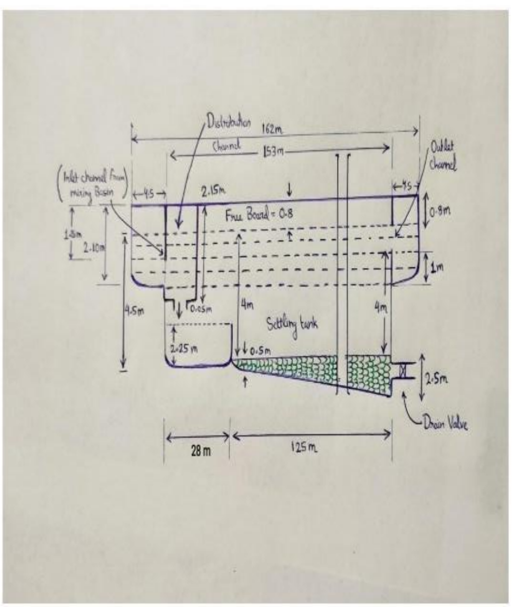
The Radial Flow Circular Tank operates by allowing water to enter through a central input pipe situated within a deflector box. The deflector box redirects the water in a downward direction. The water then moves in a radial direction from the deflector box, which has an exit along its whole perimeter, through the apertures located in the lower edges of the deflector box, towards the outer edge of the tank.
The Circumferential Flow Circular Tank operates by allowing water to enter through two or three vertical slits, while a rotating arm circulates the water along the tank's perimeter. In order to facilitate the sedimentation of suspended pollutants in the tank water, which flows at a significantly reduced speed, and then remove them through the sludge outlet



DESIGN OF THE FLOC CHAMBER

Addition to 125m length of settling Tank, the Floc Chamber at the Entry Has to be Provided.
Assuming the Effective Depth in the Floc Chamber as Half of the Depth in the tank near Floc Chamber Depth of the tank is 4.5/2= 2.25
Assuming the period of Flocculation or Detention time period as 30 min (15 to 40 min allowed) So, Flow required in 30 min
= 75 x 10^6 lit = 75 x 10^3 cu-m
(75 x 10^3/24) x 30/60 cu-m = 3125 x ½= 1562.5 cu-m

The plan Area Required= capacity/Dept = 1562.5/2.25 m^2 = 694.4m^2 ≈ 695m^2 By Using the same width as 25 m, we will get the length of Flocculation chamber



Geometrical Dimensions of Coagulation-Cum-sedimentation tank

CONCLUSION:

This study emphasizes the crucial importance of water treatment plants in guaranteeing the accessibility of potable water, which is an essential requirement for both survival and societal progress. This text examines the intricacies of these facilities, investigating their structure, functioning, and incorporation of state-of-the-art technologies, all with the goal of improving efficiency, sustainability, and quality assurance. The paper examines the difficulties encountered by conventional water treatment methods and investigates novel alternatives through a thorough analysis of existing literature and case studies. The focus is on implementing innovative technologies like as membrane filtration, sophisticated oxidation processes, and intelligent monitoring systems. This is done to improve treatment effectiveness, reduce environmental impact, and maximize resource use. The primary objective of the study is to enhance the development of strategies for water treatment facilities, promoting sustainable practices that prioritize ecological sensitivity, operational efficiency, and societal requirements. Designed as a complete reference, it caters to politicians, engineers, environmentalists, and stakeholders who are committed to promoting water treatment technologies and creating a sustainable water future for future generations.
Most of the technologies included are common in the field of WTP; therefore, the costs generated, and the sustainability assessment are reliable insights into making a holistic decision for designing WTP networks. Our superstructure-based approach integrated with the sustainability evaluation presented here can be a general guide in the selection of technologies for WTPs.

REFERENCES:

Crini, G.; Lichtfouse, E. Advantages and disadvantages of techniques used for wastewater treatment. *Environ. Chem. Lett.* **2019**, *17*, 145–155.

Khor, C.S.; Chachuat, B.; Shah, N. A superstructure optimization approach for water network synthesis with membrane separation-based regenerators. *Comput. Chem. Eng.* **2012**, *42*, 48–63.

Khor, C.S.; Foo, D.C.Y.; El-Halwagi, M.M.; Tan, R.R.; Shah, N. A Superstructure Optimization Approach for Membrane Separation- Based Water Regeneration Network Synthesis with Detailed Nonlinear Mechanistic Reverse Osmosis Model. *Ind. Eng. Chem. Res.* **2011**, *50*, 13444–13456.

Lu, B.; Huang, S.; Grossmann, I.E. Optimal Synthesis and Operation of Wastewater Treatment Process with Dynamic Influent. *Ind. Eng. Chem. Res.* **2017**, *56*, 8663–8676.

Zhang, W.; Wang, C.; Li, Y.; Wang, P.; Wang, Q.; Wang, D. Seeking Sustainability: Multiobjective Evolutionary

Optimization for Urban Wastewater Reuse in China. *Environ. Sci. Technol.* **2014**, *48*, 1094–1102. [PubMed]

Marcelino, R.B.P.; Leão, M.M.D.; Lago, R.M.; Amorim, C.C. Multistage ozone and biological treatment system for real wastewater containing antibiotics. *J. Environ. Manag.* **2017**, *195*, 110–116.

Arroyo, P.; Molinos-Senante, M. Selecting appropriate wastewater treatment technologies using a choosing-by-advantages approach. *Sci. Total Environ.* **2018**, *625*, 819–827.

Yenkie, K. Integrating the three E's in wastewater treatment: Efficient design, economic viability, and environmental sustainability. *Curr. Opin. Chem. Eng.* **2019**, *9*, 131–138.

Ku-Pineda, V.; Tan, R.R. Environmental performance optimization using process water integration and Sustainable Process Index. *J. Clean. Prod.* **2006**, *14*, 1586–1592.

Galan, B.; Grossmann, I.E. Optimal Design of Distributed Wastewater Treatment Networks. *Ind. Eng. Chem. Res.* **1998**, *37*, 4036–4048.

Yang, Y.H.; Lou, H.H.; Huang, Y.L. Synthesis of an optimal wastewater reuse network. *Waste Manag.* **2000**, *20*, 311–319.

Rigopoulos, S.; Linke, P. Systematic development of optimal activated sludge process designs. *Comput. Chem. Eng.* **2002**, *26*, 585–597.

Vidal, N.; Bañares-Alcántara, R.; Rodríguez-Roda, I.; Poch, M. Design of Wastewater Treatment Plants Using a Conceptual Design Methodology. *Ind. Eng. Chem. Res.* **2002**, *41*, 4993–5005.

Zeng, G.; Jiang, R.; Huang, G.; Xu, M.; Li, J. Optimization of wastewater treatment alternative selection by hierarchy grey relational analysis. *J. Environ. Manag.* **2007**, *82*, 250–259.

Bozkurt, H.; Quaglia, A.; Gernaey, K.V.; Sin, G. A mathematical programming framework for early stage design of wastewater treatment plants. *Environ. Model. Softw.* **2015**, *64*, 164–176

BIOGRAPHY

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