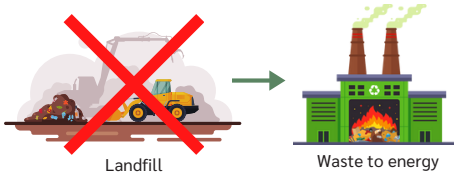
Khon Kaen University

Design of Membrane Bioreactor for Leachate Treatment System

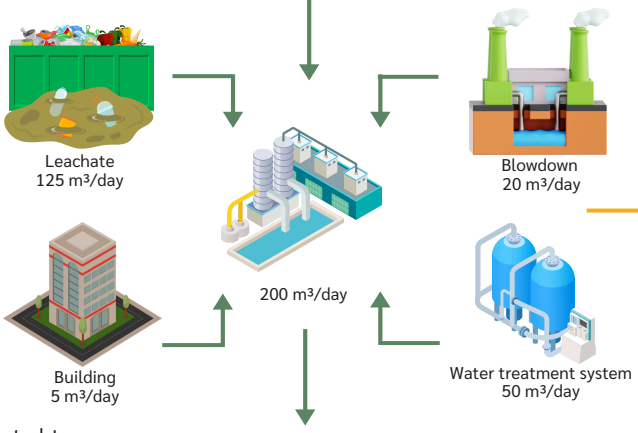
ENV2024-11: Penpitcha Chumpan, Sirorat Siriwarin, Chonthicha Khumnonchai and Natthanan Chaiphangyang
Assoc. Prof. Surapol Padungthon

Overview

A waste-to-energy plant generates wastewater 200 m³/day from various sources. This wastewater contains high concentrations that can harm the environment if untreated. While practicable wastewater treatment is essential for prevention and water reuse.



Influent wastewater characteristics			
BOD	24,000	O & G	500
COD	48,000	TSS	5,000
TKN	1,000	TDS	4,000
Unit mg/L			



Why MBR instead?

- Uses less space
- The treatment efficiency is very high
- Easy for cleaning
- Suitable for wastewater with a high level of contamination

Wastewater units

Wastewater storage tank (WWT)

It collects and stores the influent wastewater.
Sizing: 5 x 10 x 5 m

Rotary drum screen

It filters and traps small debris, causing a 10% reduction in flow rate.
Sizing: mess size 0.5 mm
Select from Techange model: ZL350 600

Equalization tank (EQ)

The incoming water is stored and its pH is adjusted to improve the efficiency of the treatment system. It also receives water from the sludge treatment process.
Criteria design: ³HRT = 6 - 24 hr (Design 6 hr)
Sizing: 6 x 6.5 x 2 m

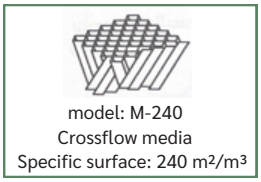
Coagulation & Flocculation tank

Coagulation tank: It enables particles that cannot settle naturally, to aggregate by adding coagulants and using rapid mixing with impeller to contact between wastewater and coagulants.
Criteria design:
[12]Mixing time 1 - 3 min (3 min)
³G 500 - 1,000 s^{-1} (500 s^{-1})
Sizing: 0.6 x 1.0 x 1.3 m

Flocculation tank: The process where these destabilized particles contact and combine to form larger particles (flocs) through slow mixing with impeller, resulting in increased weight and density that allows them to settle.
[11]Mixing time 20 - 30 min (20 min)
³G 100 - 500 s^{-1} (100 s^{-1})
Sizing: 1.0 x 2.6 x 1.9 m

Upflow anaerobic filter (UAF)

The anaerobic treatment process incorporates a media bed inside the tank, designed to take up 50% of the tank's volume. The media used is of the crossflow type and made of plastic.
Criteria design: ³HRT = 1-3 d
Media
³COD loading rate = 1-50 kgCOD/m³-d (Design 40 kgCOD/m³-d)
Sizing (tank): 5.5 x 6 x 9 m
Sizing (media): 126 m³ , D = 5 m
Select from Escore water treatment



Wastewater treatment systems

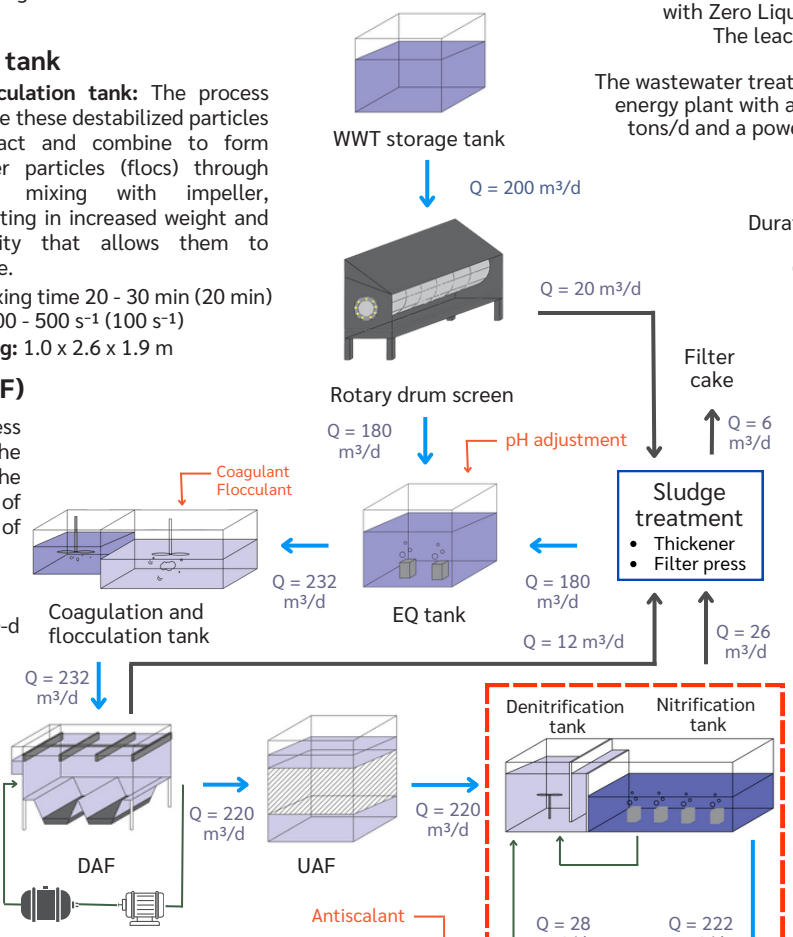


Fig. 1 Overall process

Constraints

- The wastewater recovery system must comply with Zero Liquid Discharge (ZLD) requirements.
- The leachate generated from the process must be reusable.
- The wastewater treatment is appropriate for waste-to-energy plant with a waste treatment capacity of 500 tons/d and a power generationcapacity of 9.9 MW.

Criteria

- Duration of water treatment process
- Proportion of treated water
- Concentration of effluent water
- High treatment efficiency
- Zero liquid discharge (ZLD)

Dissolved air floatation tank (DAF)

DAF dissolving air in the water to create microbubbles to float light particles to the water surface and removed by skimmers, causing a 5% reduction in flow rate.
Criteria design:
³A/S 0.005-0.060mL/mg (0.007)
[10]SLR 90 -200 kg/m²-d (150)
[10]HLR 90 - 250 m³/m²-d (120)
Sizing: 2.400x1.618x2.416 m
Select from Siltbuster water quality matters

Sludge treatment system

There is a sludge treatment system and reduces water content in the sludge. The water separated from the sludge will be treated again in the equalization tank, without discharge according to Zero liquid discharge (ZLD). The process includes sludge thickener and sludge dewatering.
Filter cake : 20%

Wastewater units (Cont.)

Membrane bioreactor tank (MBR)

Nitrification Zone: The process of converting ammonia (NH_3) into nitrite (NO_2^-) and then nitrate (NO_3^-) by nitrifying bacteria.

$$NH_3 + O_2 \rightarrow NO_2^- + 3H^+ + 2e^-$$

$$NO_2^- + H_2O \rightarrow NO_3^- + 3H^+ + 2e^-$$

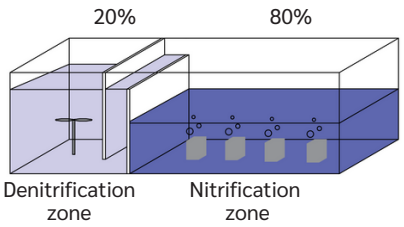


Fig. 2 MBR tank

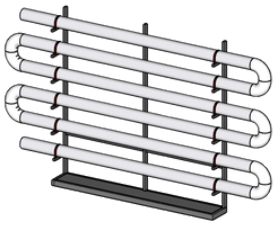


Fig. 4 UF

Fig. 3 Diffuser

Denitrification Zone: The process of converting nitrate (NO_3^-) back into nitrogen gas (N_2), which is released into the atmosphere by denitrifying bacteria.

$$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$$

The nitrification tank, which requires oxygen for efficient operation, is equipped with **aeration systems**. The aerators are selected based on the calculated Air Flowrate derived from the Standard Oxygen Transfer Rate (SOTR) to ensure optimal oxygen transfer for the biological process.
Swirl diffusers from Hydrosys were selected for aeration, with a total of 84 units, each operating at an Air Flowrate of 1 m³/min.

$$SOTR = \left(\frac{OTR_f}{\alpha F}\right)\left\{\frac{C_{\infty 20}}{\beta \frac{C_{st}}{C_{s20}}\left(\frac{P_b}{P_a}\right)(C_{\infty 20}) - C_L}\right\} 1.024^{20-T}$$

Tank size is designed based on the Organic Loading Rate (OLR)

$$V = \frac{\text{Load } COD_{in} - \text{Load } COD_{out}}{OLR}$$

Criteria design: [3]MLSS 8-12 kgMLSS/m³ (Design 12)
[4]COD-sludge loading 0.08-0.30 kgCOD/kgMLSS/d (Design 0.23)
[9]De-nitrification rate 0.12-0.90 kgNO3-N/kgMLSS/d (Design 0.16)
[9]COD sludge yield 0.15-0.20 kgMLSS/kgCOD removed (Design 0.15)

The **MBR tank volume** is divided into two sections: the nitrification tank (80%) with dimensions of 7.5×11.5×7 m and the denitrification tank (20%) with dimensions of 2.5×7.5×8 m

Removal efficiency in MBR tank: BOD 90%, COD 95%, O&G 100%, TSS 100%, and TKN 85%.

Excess sludge generation in MBR tank: Dry sludge 308.02 kg MLSS/day and Wet sludge 26.00 m³/day.

Reverse Osmosis (RO)

Cartridge filter: It is often used as a pre-filter before a reverse osmosis (RO) system to remove large particles and protect the RO membrane from clogging and damage. So that we choose melt-blown for depth filtration and multi-layer and cheaper than other types the quality may not be as good as other but we already have UF membrane before RO membrane.

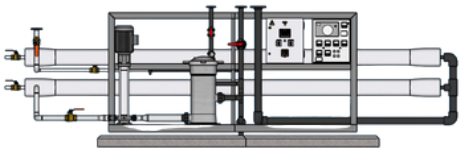
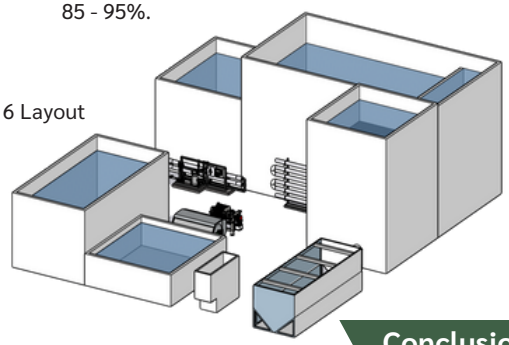


Fig. 5 RO

Ultrafiltration: The process of pretreatment step before Reverse Osmosis (RO) in water purification processes. UF are selected based on the flux rate 50 - 100 LMH (Berghof membrane catalog). The flux rate obtained is used to calculate the required membrane area. Then, the membrane area per module and the number of modules are used to determine the chosen membrane area, which must be greater than the required membrane area, design criteria selected from Berghof company. The [4]recovery percentage should be between 85 - 95%.

Reverse Osmosis: This is a membrane-based water purification process that removes total dissolved solids (TDS), contaminants and impurities from water by applying pressure to force it through a semi-permeable membrane. Reverse osmosis can removes up to 95 - 99% (Vontron membrane catalog) of total dissolved solids. The calculation of the chosen membrane area for the RO membrane follows the same method as for UF. Additionally, osmotic pressure is calculated to determine the pump specifications, with a [1]recovery percentage of 50 - 85%. Wastewater produces permeate that can be reused in processes while the highly concentrated water can be repurposed for industrial cooling applications.

Fig. 6 Layout



Result

Wastewater effluent

Wastewater system	BOD	COD	O & G	TSS	TKN	TDS
Wastewater influent	24,000	48,000	500	5,000	1,000	14,000
Rotary drum screen	18,000	36,000	450	2,750	1,000	14,000
Equalization tank	18,000	36,000	450	2,750	1,000	14,000
Coagulation & Flocculation tank	15,300	30,600	405	2,475	850	14,000
Dissolved air flotation (DAF)	11,475	22,950	8	248	680	14,000
Upflow anaerobic filter (UAF)	4,016	9,180	8	124	544	14,000
Membrane bioreactor (MBR)	201	918	0	0	82	14,000
Reverse osmosis (RO)	8	90	0	0	20	700
Standard discharge	≤20	≤120	≤5	≤50	≤100	≤3,000

Unit mg/L

Conclusions

- The leachate wastewater treatment system operates with a Membrane Bioreactor (MBR) in combination with other treatment processes, which is effective in intensive wastewater treatment, significantly reducing BOD, COD, O&G, TSS, and TKN levels.
- Membrane filtration enhances treatment efficiency by trapping pollutants. MBR treatment lowers pollutant levels before Reverse Osmosis (RO), extending membrane lifespan, and cutting maintenance costs. RO further purifies water by reducing Total dissolved solids (TDS).
- The sludge dewatering system efficiently separates water from sludge, reducing water loss and allowing for its reuse in the treatment process. This step reduces sludge disposal and conserves water resources.
- The high concentration reject water (58.20 m³/day) is utilized in internal plant processes, such as cooling ash in power plant. The permeate water (135.80 m³/day) is clean enough for various applications, including irrigation within the power plant area and as flushing water in sanitation systems.
- This process does not discharge wastewater from the system, in line with the Zero Liquid Discharge (ZLD) concept.

References

[1] Zhewei, Z. (2021). ***Pretreatment of brackish water reverse osmosis concentrate to enhance water recovery.***
[2] ESCORE Water treatment system, (2019). ***ESCORE MEDIA SERIES***
[3] Metcalf & Eddy, (2014). ***Wastewater Engineering.***
[4] *PCI Membranes filtration Group. (2023).* ***Design of membrane plants.***
[5] Pearce, G.K. (2007). ***The case for UF/MF pretreatment to RO in seawater applications.***
[6] Techange, (2016). ***ZL modlr drum filter.***
[7] เกรียงศักดิ์ อุดมสินโรจน์. (2543). ***วิศวกรรมการกำจัดน้ำเสีย เล่ม 3. พิมพ์ครั้งที่ 1.***
[8] เกรียงศักดิ์ อุดมสินโรจน์. (2543). ***วิศวกรรมการกำจัดน้ำเสีย เล่ม 4. พิมพ์ครั้งที่ 1.***
[9] ธงชัย พรรณสวัสดิ์. (2544). ***การกำจัดไนโตรเจนและฟอสฟอรัสทางชีวภาพ. พิมพ์ครั้งที่ 1.***
[10] สมาคมวิศวกรรมสิ่งแวดล้อมแห่งประเทศไทย. (ไม่ปรากฏปี). ***เกณฑ์การออกแบบ DAF.***
[11] Davis. (2010). ***Water and Wastewater Engineering.***
[12] Minnesota Rural water association. n.d. ***Coagulation and Flocculation***