



00:53

Water Crisis & Resource Recovery

- Global annual water consumption for agricultural, industrial and urban use is around 4 trillion cubic meter and increasing
- The polluted wastewater generation worsens the water availability
- Water reuse necessary for augmenting water availability
- Water reuse requires treatment technologies & therefore cost input
- Resource recovery methodologies can make treatment methods cost-effective & sustainable

wastewater a repository of resources

05:57

Resource Recovery: Introduction

- Linear economy model

Circular economy model

22:38

[illegible]

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27:31

Resource Recovery Technology: Anaerobic Digestion

- Suitable for energy recovery from wastewater as biogas
- Ideal for wastewater with high BOD and COD (>1 g/L)
- The common types of AD are UASB and FB reactors
- Approximately, 0.4-0.5 Nm³ biogas/kg of COD have reportedly been produced by treating brewery wastewater
- The energy production of 39 MJ/m³ of treated wastewater with influent COD of ~4 g/L
- Low sludge production, low space requirements, slow reaction kinetics
- Unable to remove nutrients; the supernatant contains ammonium and phosphate ions

By Tilley, E., Ulrich, L., Lipp, J., & ... (2019). *Compendium of Sanitation Systems and Technologies* (2nd Revised Edition). Swiss Federal Institute of Technology (EPFL). ISBN 978-3-90484-574-1. CC BY-NC-ND 4.0. <https://commons.wikimedia.org/wiki/index.php?curid=42267210>

29:41

Bio-electrochemical Systems: Microbial Fuel Cells

- MFCs are suitable for electricity generation from BOD rich wastewater
- Electroactive bacterial species produced current from chemical energy contained in the organic biodegradable substrate at anode as:

$$\text{CH}_3\text{COO}^- + 4\text{H}_2\text{O} \rightarrow 2\text{HCO}_3^- + 9\text{H}^+ + 8\text{e}^-$$
- At cathode, oxygen reduction reaction takes place as:

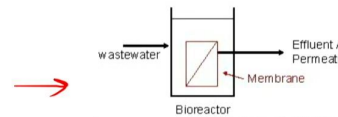
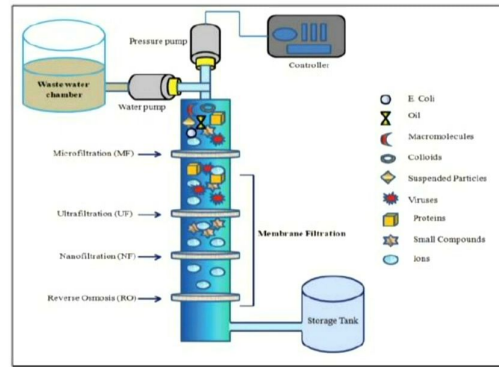
$$2\text{H}_2\text{O} + \text{O}_2 + 4\text{e}^- \rightarrow 4\text{OH}^-$$
- An ion-exchange membrane separates the two chambers and allows ions to pass through it to maintain the electroneutrality
- MFCs can be useful for removing >90% COD and recovering ammonia from organic matter with simultaneous energy generation

Nawaz & Sengupta, Wastewater: novel treatment technologies and source of epidemiological studies, Elsevier 2021

31:03

Membrane-based Systems

- Mainly a water reuse technology
- As a standalone process, membranes can be used for tertiary polishing step
- In combination with biological treatment systems, membranes can be used as Membrane Bioreactors (MBRs)
- An MBR (Anaerobic MBR) can perform joint digestion and water treatment leading to both energy and water recovery
- UF membranes have been reported to recover proteins and lipids from seafood processing wastewater and whey protein from dairy wastewater
- Membrane fouling is a major issue



Submerged MBR

By M brannock at English Wikipedia, CC BY-SA 3.0,
<https://commons.wikimedia.org/w/index.php?curid=38814608>

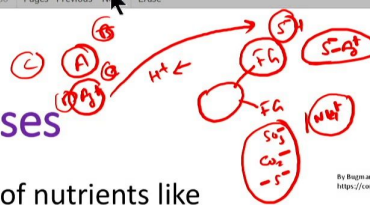
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Navvar et al., Food Processing Wastewater Treatment: Current Practices and Future Challenges, Springer, 2021

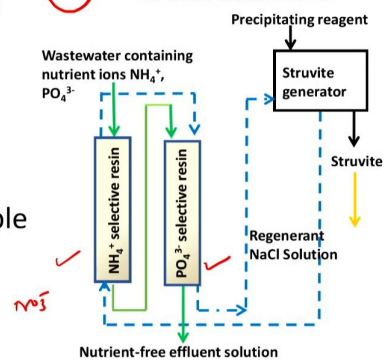
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Ion-Exchange Processes

- Suitable for selective recovery of nutrients like ammonium, nitrate and phosphate ions
- Typically used at the end of process train to selectively scavenge low concentration ions
- Requires regeneration and further recovery steps using chemical reagents
- The resins and regenerants can be used multiple times to bring down the material cost of treatment
- Easy to scale-up and operate



ion-exchange resin beads



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Algal Processes

- Suitable for recovering biofuels, nutrient supplements, pigments, fertilizers and other bioactive substance with simultaneous COD removal and nutrient removal
- Steps to promote the cultivation of algae in a wastewater

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graph LR
    A[Pre-treatment of wastewater] --> B[Selection of algal species]
    B --> C[Optimization of media mix and dilution of wastewater]
    C --> D[Adaptation of algae in wastewater]
  
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- Chlorella, Spirulina, Dunaliella are some of the major algal species used for high BOD wastewater
- Algal species can be useful in MFC due to carbon fixation and higher DO (by photosynthesis)
- Difficult to scale-up
- Land requirement, availability of sunlight and temperature are important criteria
- Requires addition of growth nutrients and a certain N:P ratio in wastewater

Human nutrition
Source of proteins, carbohydrates, vitamins and essential minerals for human nutrition

Animal nutrition
Source of proteins, carbohydrates, vitamins and other compounds adequate for animal feed formulations

Nutraceuticals/food additives
Source of β -carotene, astaxanthin, PUFA, lutein and phycoerythrin, with application as nutraceuticals and food additives

Cosmetics/pharmaceuticals
Source of β -carotene, astaxanthin, PUFA, phycoerythrin and other specialty compounds, with application in cosmetics and pharmaceuticals

Biosensors
N- and P-rich biomass residue as feedstock for the production of biofertilizers

Wastewater treatment
Nutrients removal from wastewaters

CO₂ capture
From the atmosphere or flue gas emissions

Bioenergy
Bulk oil feedstock for jet fuels and biodiesel
Biomass residue as feedstock for bioethanol, biogas, bio-char and biohydrogen

Image: <https://www.sciencedirect.com/topics/earth-and-planetary-sciences/microalgae>

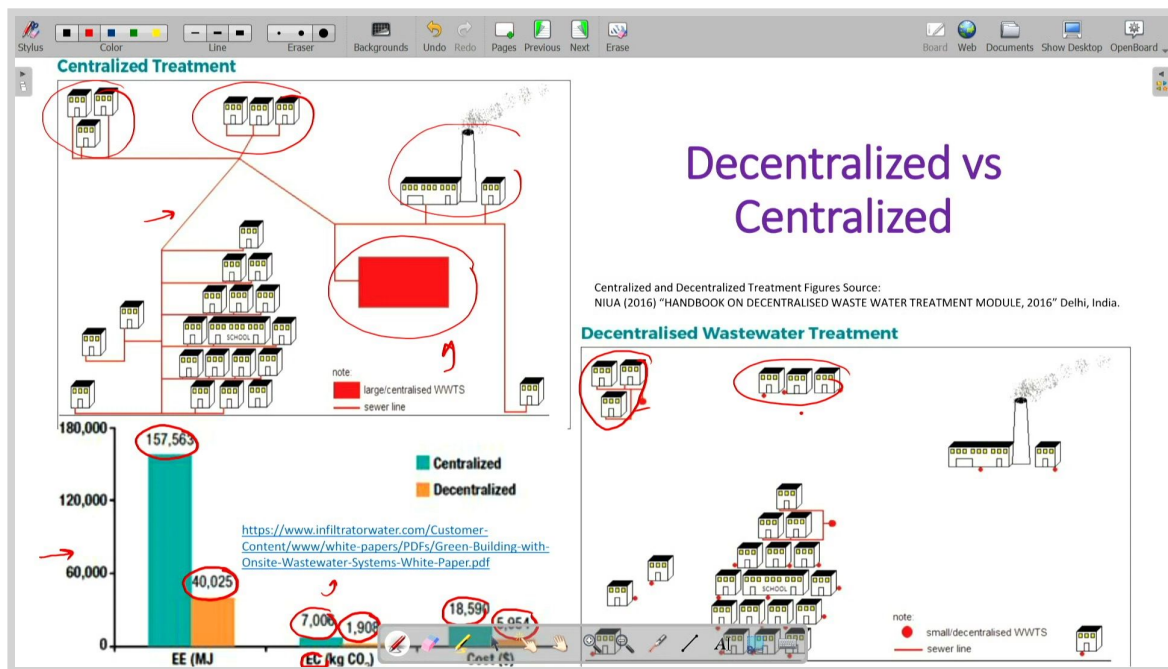
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Decentralized Wastewater Treatment

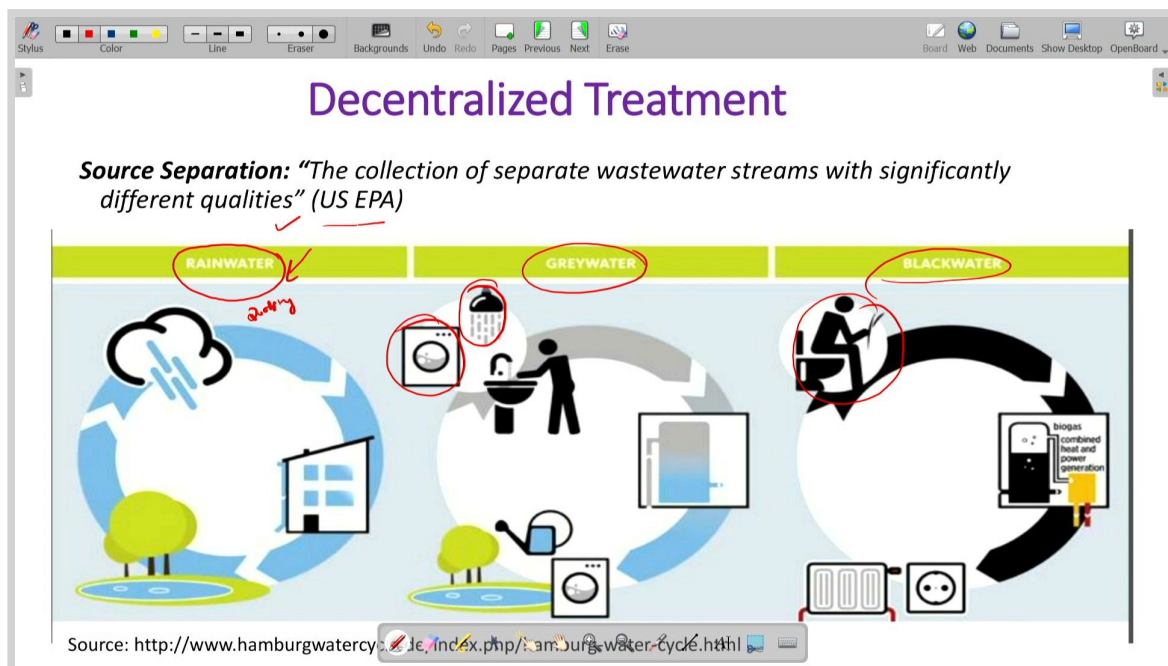
"The collection, treatment, and disposal of wastewater from individual homes, clusters of homes, isolated communities, industries, or institutional facilities, as well as from portions of existing communities at or near the point of waste generation" (Tchobanoglous, 1995)

- It is just a technical approach, the objective remains same as the conventional centralized wastewater treatment plants (WWTPs)
- The treatment is at or near the source, preferably within 3-5 Km with wastewater from single or few households
- Almost all current wastewater treatment technologies could theoretically be applied for decentralized wastewater treatment

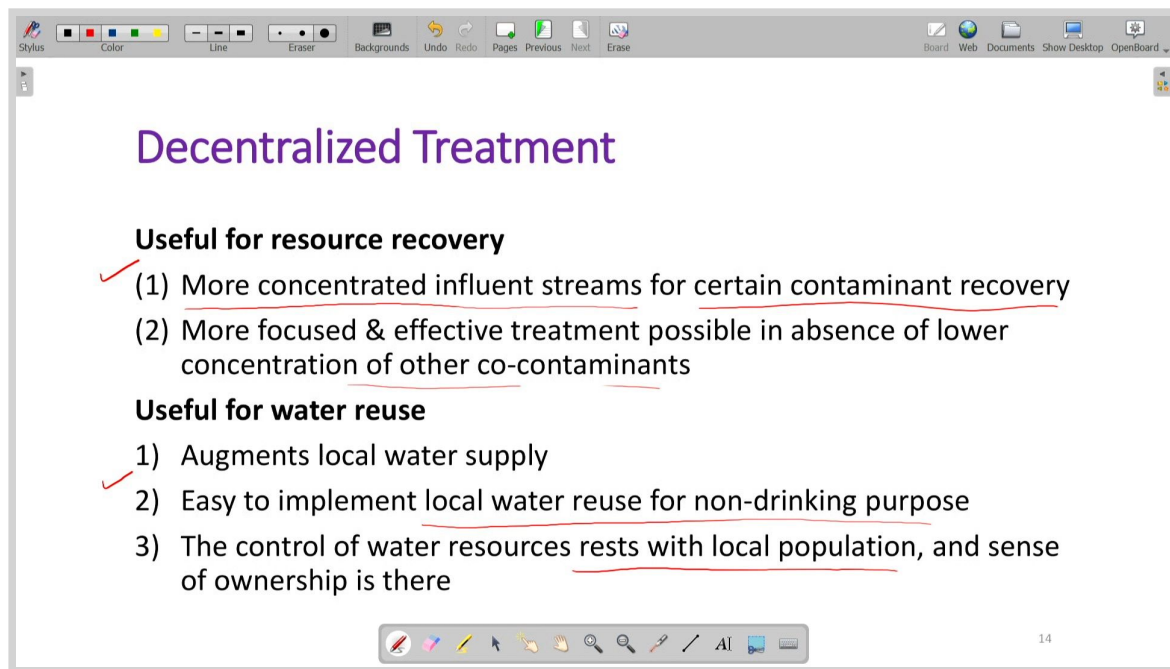
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Decentralized Treatment

Useful for resource recovery

- ✓ (1) More concentrated influent streams for certain contaminant recovery
- (2) More focused & effective treatment possible in absence of lower concentration of other co-contaminants

Useful for water reuse

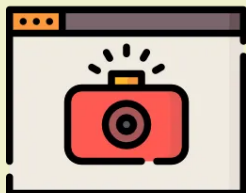
- ✓ 1) Augments local water supply
- 2) Easy to implement local water reuse for non-drinking purpose
- 3) The control of water resources rests with local population, and sense of ownership is there

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