Wastewater remediation issues

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Introduction

– Water is necessary for all known life forms
– Water pollution and enviromental degradation are on the rise
– As result of globalization, industrialization, population increase and urbanization, water contamination has become major issue
– The use of reclaimed wastewater for irrigation has become an attractive alternative water resource

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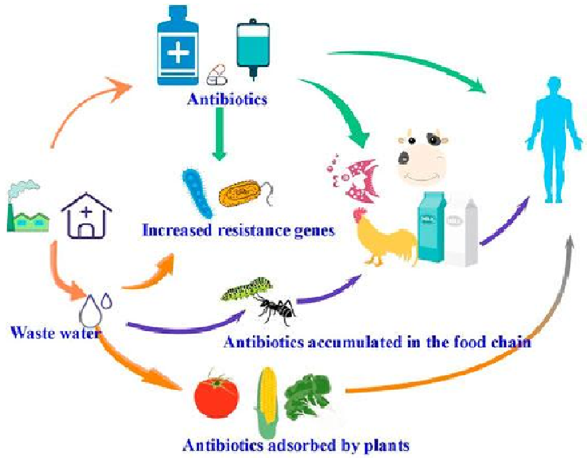
Introduction

- However, there are several potential environmental- and health-related risks associated with this practice
- One significant issue associated with wastewater treatment is the presence of antibiotic residues. Antibiotics are commonly used in healthcare, agriculture, and livestock farming
- When these antibiotics enter wastewater through various sources like hospitals, pharmaceutical manufacturing, or agricultural runoff, they can persist through the treatment process and end up in the treated effluent
- The presence of antibiotic residues in wastewater is concerning due to its potential environmental and public health impacts. Antibiotics in treated wastewater can contribute to the development of antibiotic-resistant bacteria in the environment
- Addressing antibiotic residue problems in wastewater treatment requires improved treatment processes, proper disposal of expired or unused medications

What can antibiotic residues in nature cause?

- **Antibiotic resistant development**
- **Ecotoxicity** (residues in water bodies can be toxic to organisms. Even at low concentrations, antibiotics may negatively impact the growth, development, and survival of aquatic organisms)
- **Disruption of microbial communities** (This can affect nutrient cycling, decomposition processes, and other essential ecosystem functions, leading to imbalances in the ecosystem)
- **Persistence** in the environment (some antibiotics are persistent in the environment, meaning they do not easily break down = accumulation)
- **Transfer through food chains** (residues can enter the food chain, which potentially leads to unintended exposure)



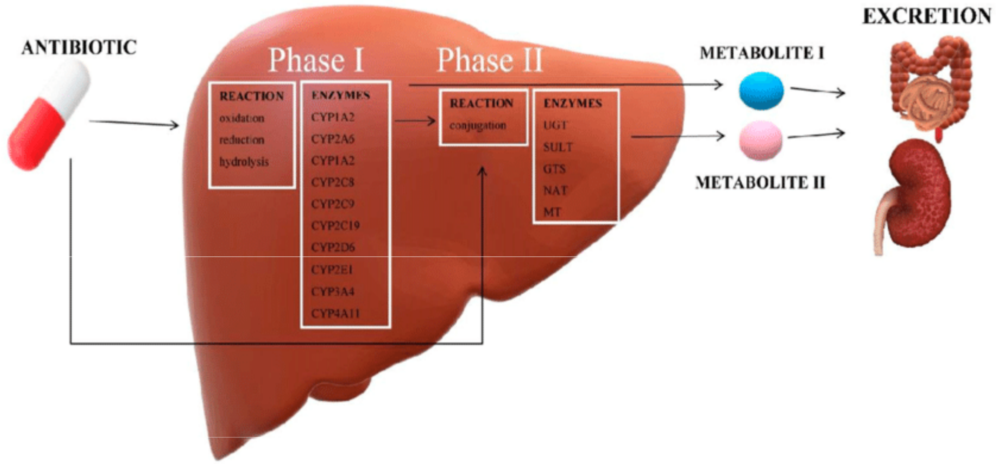
Antibiotics metabolism

- After distribution in the tissues and body fluids, metabolising enzymes in the body may degrade the ATB
- The liver is the principal organ of metabolism, although any biological tissue can metabolised drugs
- By metabolic processes, the drug is inactivated and converted into more readily excreted substance
- Not all ATB are converted to metabolites and, on occasion, the metabolites may retain activity

 https://www.sciencedirect.com/science/article/abs/pii/B978012397043500013X

Antibiotics metabolism

- Unchanged ATB and ATB metabolites are removed from the body by excretion pathways
- Excresion as urine from the kidneys are the major route of drug elimination
- Excresion into the bile from the liver is another



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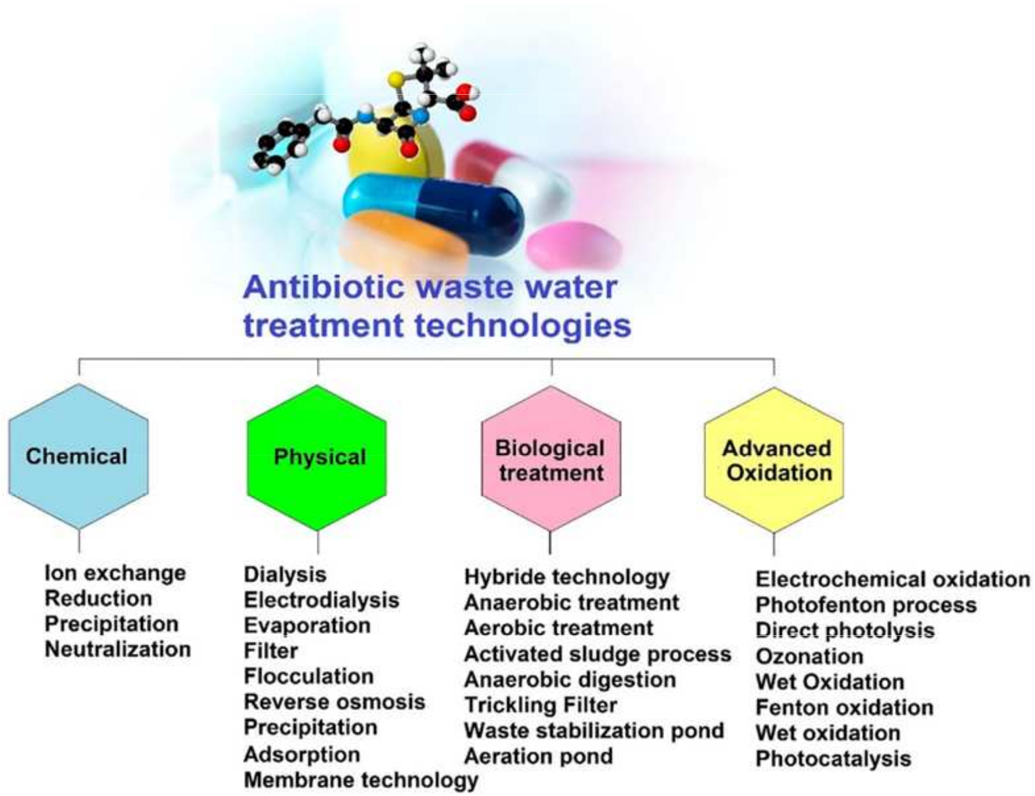
Issues of ATB removal from water – avaible methods

- Various technologies based on physical, chemical and biological techniques, such as flocculation and coagulation, membrane filtration, advanced oxidation process and bioremediation method, have been used for wastewater treatment.
- Unfortunately, the currently available methods do not allow cleaning from all antibiotic residues



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Photocatalytic degradation

- Water is one of the most important components of life
- In past few years, the concern towards contaminants like pharmaceutical compounds (PCs) has increased due to their impacts on the ecosystem
- Amoxicilin (AMX) is primarily used as semi-synthetic penicillin which belongs to the β-lactam group of antibiotics
- AMX is responsible for obstruction of bacterial cell wall synthesis
- Advanced Oxidation Processes (AOPs) are reported as the most effective technique to treat recalcitrant compounds like PCs

 Verma a Haritash, „Photocatalytic degradation of Amoxicillin in pharmaceutical wastewater".

Photocatalytic degradation

- Ptohocatalysis is based on the degradation of highly oxidizing hydroxyl radicals (•OH)
- •OH are strong oxidizing agents which transform pollutants to non-toxic end products like CO_2 and H_2O
- Heterogenous photocatalysis is found to be the most efficient method to degrade complex pollutants like ATB
- Photocatalysis initiates when semiconductor photocatalyst is exposed to light (IR, VIS, UV)
- Various photocatalysts have been used
- TiO_2 is most effective as it represents nontoxicity, photo-reactivity, high photostability, chemical and biological inertness and low prize

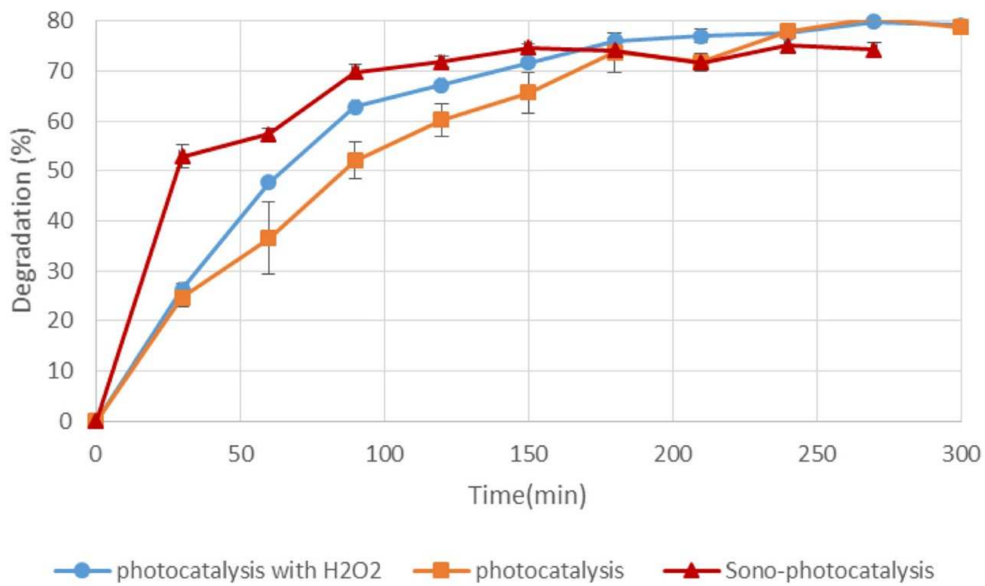
 Verma a Haritash, „Photocatalytic degradation of Amoxicillin in pharmaceutical wastewater".

Experimental procedure of photocatalysis

- The experiments for photocatalytic degradation were preformed at initial AMX concentration of 10, 30, 50 mg/l in 200 ml aqueous solution
- The pH of the solution was adjusted to 3, 7, 11 (using H_2SO_4, NaOH)
- Thereafter, varying dosages of TiO_2 (300, 450, 600 mg/l) and H_2O_2 were added
- The real industrial wastewater of AMX producing batch was collected from pharmaceutical industry located in India

Results of photocatalysis

- To observe the degradation of AMX, experiments were performer using photocatalysis with H_2O_2, without H_2O_2 and sono-photocatalysis
- Maximum degradation for AMX was obtained using photocatalysis with H_2O_2 at AMX 30 mg/l, TiO_2 450 mg/l, H_2O_2 150 mg/l and pH 7
- The result revealed that there was no significant improvement in maximal degradation when photocatalysis was amended with H_2O_2



 Verma a Haritash, „Photocatalytic degradation of Amoxicillin in pharmaceutical wastewater".

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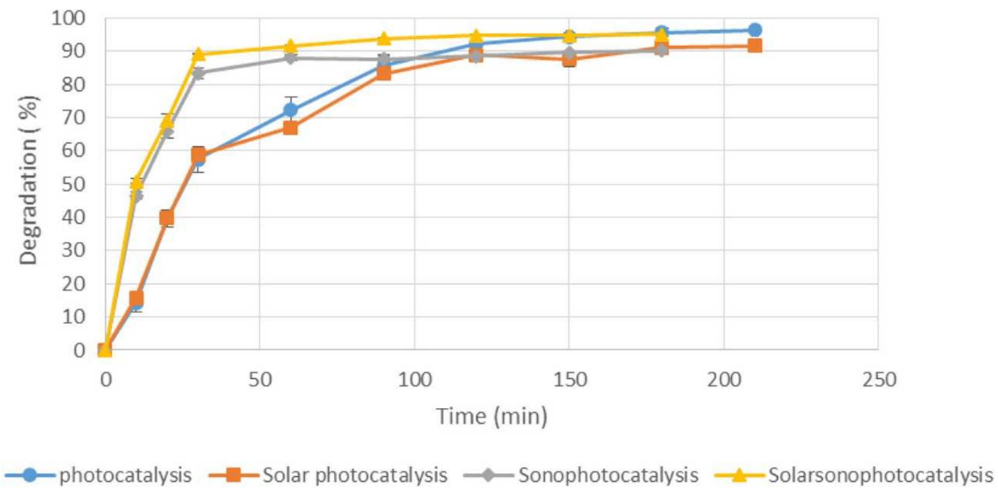
Results of photocatalysis in pharmaceutical wastewater

- Within 10 min of reaction time it was achieved 50 % of degradation in sono-catalysis and solar sono-catalysis
- After 30 min, more than 80% degradation was found in sono-catalysis and solar sono-catalysis and more than 50% degradation in photocatalysis and solar-photocatalysis



 Verma a Haritash, „Photocatalytic degradation of Amoxicillin in pharmaceutical wastewater".

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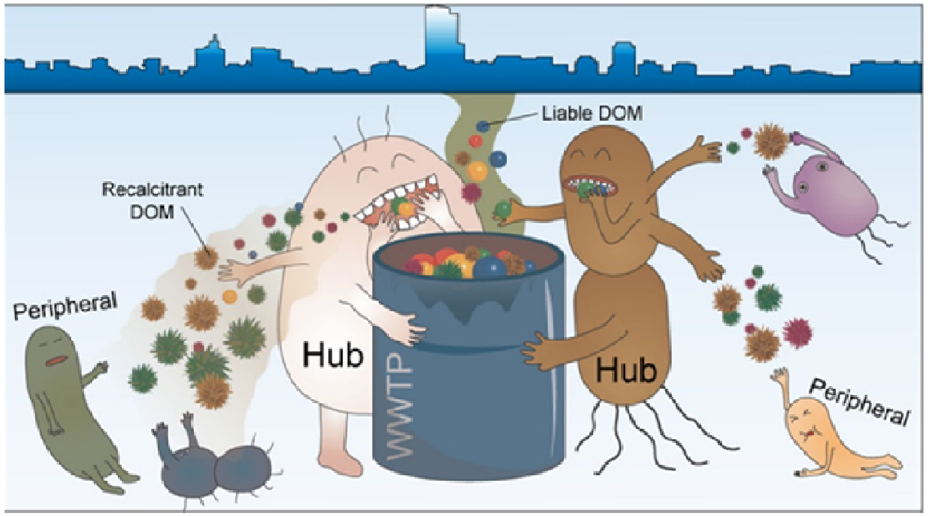
Microbial biofilm reactors

- The biological approach for wastewater treatment is not only a widely used technology, but it is also an environmentally safe and user-friendly approach over physical and chemical-based treatment methods
- **Biofilms**: are dynamic, structurally complex systems having characteristics of multicellular animals and multiple ecosystems – so biofilm have a different physiology than planktonic cells
- Biofilm reactors may be traced all the way back to the beginnings of modern water sanitation.
- Researchers used a biofilm-covered media dosed with a steady trickle flow.
- More research is still needed

 Verma, Kuila, a Jacob, „Role of Biofilms in Waste Water Treatment".

How it works

- Biofilm system is a well-developed approach where solid medium is introduced to suspended growth reactors to create adherence sites for biofilms, hence increasing microbial concentration and pollutant breakdown rates
- Biofilms can accumulate, degrade and break down pollutants, including antibiotic residues
- Degradation and decomposition in concentrations of up to several hundred ng g^{-1}
- After the pollutants have been removed, the area will be treated and biofilter's water is either discharged into the environment or utilized for agriculture etc.



 Verma, Kuila, a Jacob, „Role of Biofilms in Waste Water Treatment".

The mechanism by which biofilms contribute to the removal of antibiotic residues in wastewater

- **Adsorption**: Biofilm matrices can adsorb and physically trap antibiotic molecules. The EPS produced by microorganisms in the biofilm can act as a sorbent, capturing antibiotics as they pass through the reactor

- **Microbial degradation:** Within the biofilm, diverse microbial communities can thrive. Some of these microorganisms possess the ability to biodegrade or transform antibiotics into less harmful compounds. Microbial metabolism can break down complex organic molecules, including antibiotics, through enzymatic reaction

- **Sorption to microbial biomass (accumulation):** Antibiotics can be sorbed into the biomass of microorganisms within the biofilm. Microbes can act as carriers for the antibiotics, facilitating their removal from the water

- **Biological transformation:** Certain bacteria in the biofilm may have the capability to enzymatically degrade or transform antibiotics into less toxic forms, reducing their environmental impact

 Verma, Kuila, a Jacob, „Role of Biofilms in Waste Water Treatment".

Advantages of biofilm reactors

- Increased residence time of biomass
- Environmental resistance
- Low space requirements
- Flexibility of operation, and hydraulic retention time is reduced
- It improved capacity to digest refractory substances as well as a slower pace of microbial growth, results in less production of sludge
- Availability - because they are found everywhere in nature and in manmade systems
- Offers sustainable wastewater treatment

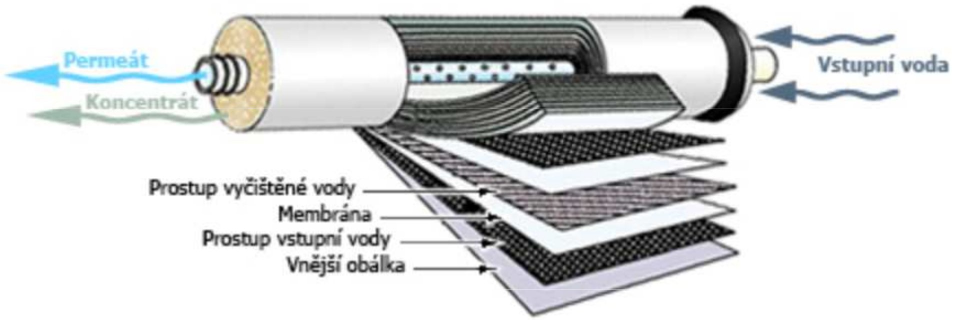
But…

- Effectiveness can vary depending on factors such as the specific antibiotic, the composition of the biofilm, and the overall wastewater treatment process. Integration of biofilm reactors with other treatment technologies, such as activated sludge processes or advanced oxidation methods, may be necessary to achieve comprehensive removal of antibiotic residues from wastewater

 Verma, Kuila, a Jacob, „Role of Biofilms in Waste Water Treatment".

Membrane technologies

- Biological treatment is a potential solution, the high cost limits its use in large plants
- The effectiveness is related to the solute and membrane properties (size of membrane pores)
- Fabricating negatively charged membranes can reduce the total cost of the filtration process
- A combination of membrane processes with advanced oxidation processes (AOPs), adsorption, and biological treatments - right solution for perfect removal

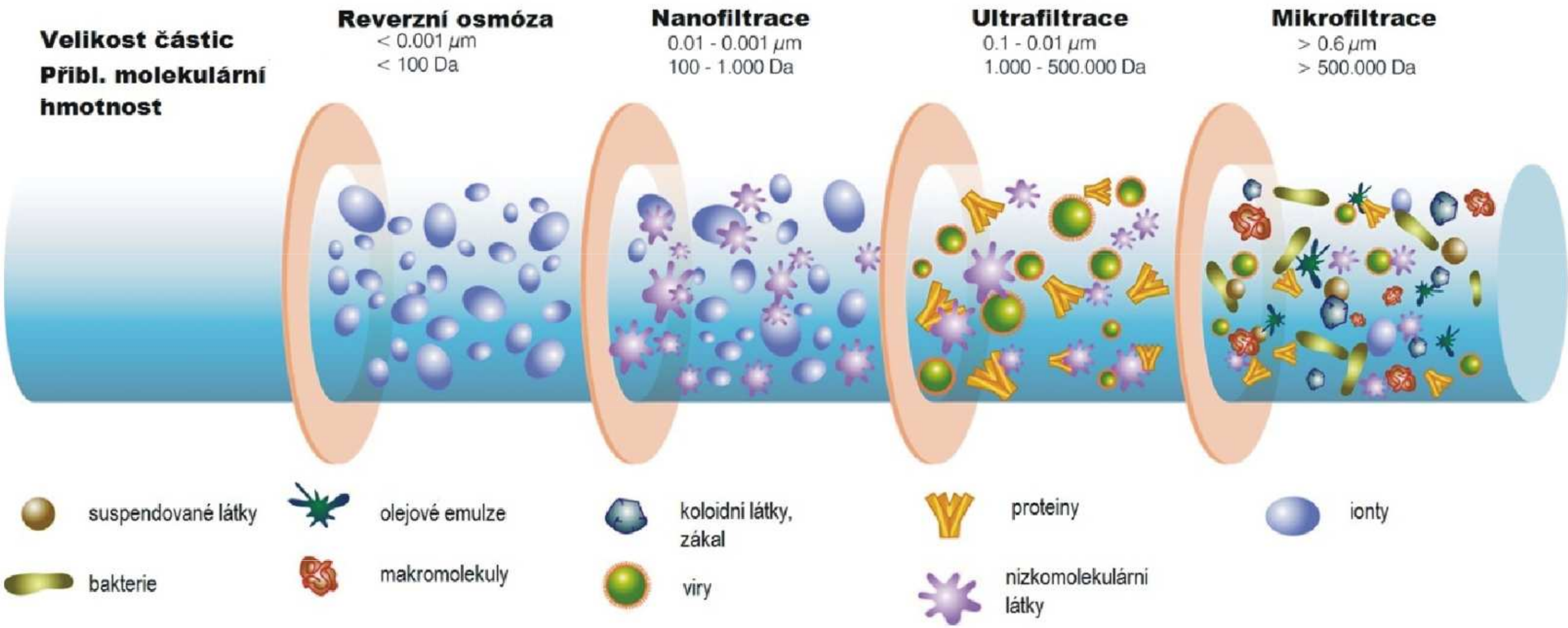


 „Removal of Antibiotics from Wastewaters by Membrane Technology".

Types of membrane technologie

- **Microfiltration** (pores 0.1-10μm) – removes bacteria, particles, microorganisms with some kinds of antibiotics
- **Ultrafiltration** (pores 0,001 to 0,1μm) – removes bacteria, viruses, organic substances including antibiotics
- **Nanofiltration** (nanometres pores) – removes organics, ions and some types of antibiotics
- **Reverse osmosis** – effective for removing a wide range of contaminants, including antibiotics, removing molecules with high molecular weight

 „Removal of Antibiotics from Wastewaters by Membrane Technology".

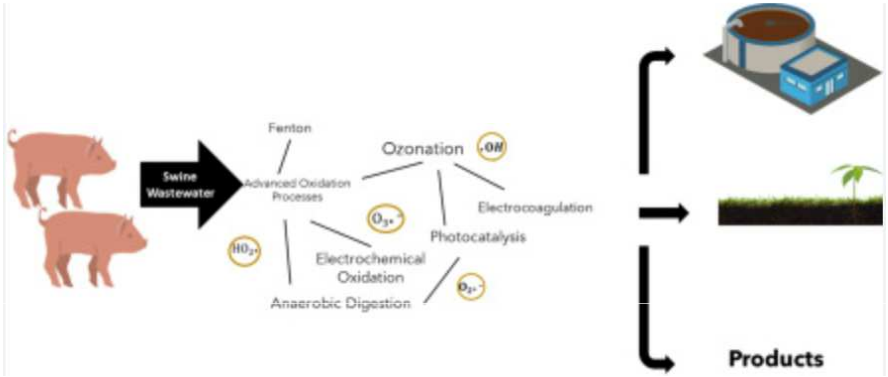


Velikost částic
Přibl. molekulární hmotnost
Reverzní osmóza
< 0.001 µm
< 100 Da
Nanofiltrace
0.01 - 0.001 µm
100 - 1.000 Da
Ultrafiltrace
0.1 - 0.01 µm
1.000 - 500.000 Da
Mikrofiltrace
> 0.6 µm
> 500.000 Da
suspendované látky
olejové emulze
koloidní látky, zákal
proteiny
ionty
bakterie
makromolekuly
viry
nizkomolekulární látky

How it works

- An original fact about membrane is the division of the feed into two streams, which are permeate and retentate where both streams may be important
- In water treatment permeate is the main product of process
- Membrane is able to transfer one component of the feed stream easier than others because of the special properties and different relationships between the membrane and permeating components

Experient



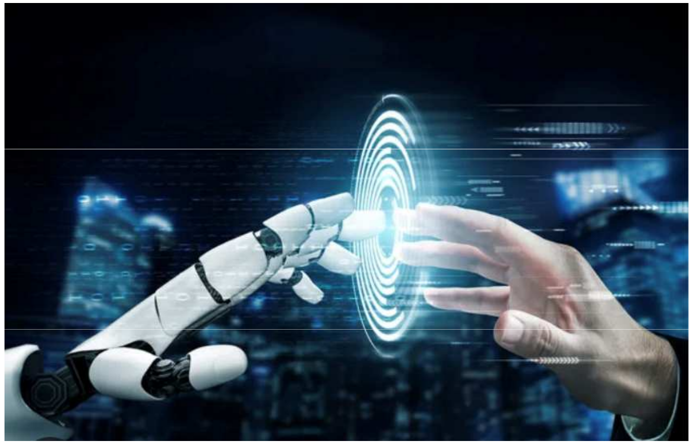
- One of the main sources

of ARGs is the swine wastewater treatment plant

- Increases the efficiency of NF and RO in ARGs elimination from swine wastewater
- Conventional biological treatment did not reduce the high abundance of ARGs in raw wastewater
- NF and RO were effective processes to remove ARGs
- Advanced membrane technologies could remove different kinds of ARGs efficiently

Promising methods for the future

- A combination of different technologies can provide a more efficient approach
- Removal of antibiotics and relative toxic compounds can be used as energy generation plants to reduce WWTP costs in future
- Development of advanced oxidation processes - photo-oxidation, Fenton reactions (catalytic oxidation of hydrogen peroxide) ozonation - using oxidation processes to break down organic substances, including antibiotics.



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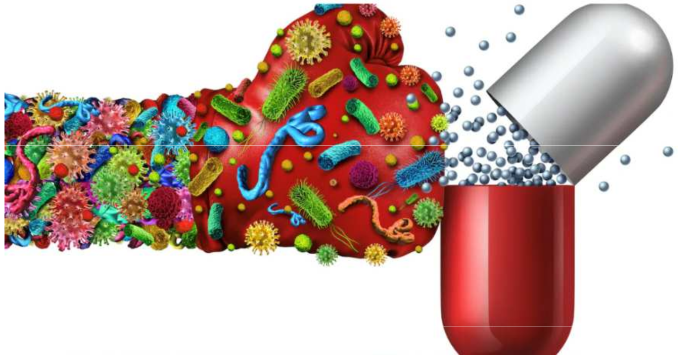
- Techniques for the removal of antimicrobial resistance uses advanced technologies - anaerobic or aerobic treatment reactors, constructed wetlands, chemical disinfection, coagulation, biochar, and more recently, nanotechnology

Nanotechnology

- Metal oxide nanomaterials such as TiO_2 are among the promising nanocatalysts that were tested successfully for their antimicrobial activity.
- Nanoparticles act as delivery systems for the established antimicrobials by transporting them to the target sites
- Examples of this include silica nanocarriers, liposomes, polymeric nanocarriers, micellar nanocarriers and many more
- Silver-based nanomaterials, Titanium dioxide based nanomaterials, Carbon based nanomaterials

 Saraswat, „Application of Nano-Biotechnology in Wastewater Treatment".

- Materials only kill the cell wall of these resistance organisms and failed to penetrate into the nucleus of the cell (does not destroy the nucleic acid)
- Surface of nucleic acids is negatively charged, the development of a nanoparticle with a positive surface charge will effectively remove this substance from wastewater by electrostatic interaction



 Bora a Dutta, „Applications of Nanotechnology in Wastewater Treatment—A Review".

Conclusion

- Photocatalysis with TiO_2 is a potential and effective method for degradation of AMX in pharmaceutical wastewater
- Since solar-photocatalysis produced promising results, it may be regarded as sustainable, low-cost, viable, and efficient green technology for the treatment of residual ATB in wastewater
- Microbial biofilm reactors are a sustainable and efficient solution, especially in combination with other methods
- Nanotechnology holds great promise for the future due to its ability to disrupt cell wall of resistant pathogenic microorganisms

Thank you for your attention!

Questions

- What can antibiotic residues in the environment cause?
  - Increase the biodiversity of mikroorganisms
  - They are toxic for humans
  - They contribute to the spred of antibiotic resistence

  - Answer**: They contribute to the spred of antibiotic resistence**

Questions

- What are the mechanism by which biofilms help in wastewater treatment?
  - Completely decompose antibiotics
  - They leach antibiotics from the water
  - They don´t help in any way

  - Answer: **They leach antibiotics from wastewater**

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Questions

- Why is the use TiO_2 suitable for photocatalysis degradation?
  - Easy and quick
  - Nontoxicity, low prize
  - Scientists are lazy

  - Answer: **Nontoxicity, low prize**

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Questions

- Which method seems applicable for the treatment of pharmaceutical wastewater?
  - Solar-photocatalysis
  - Photodegradation
  - Osmosis
  - Reverse osmosis

  - Answer: **Solar-photocatalysis**

Questions

- How does nanotechnology kill microorganims?
  - They don´t kill them and they are beneficial for microorganisms
  - They disrupt the cell wall
  - They interfere with nucleic acid

  - Answer: **They disrupt the cell wall**

Questions

- What are the advantages of biofilm reactors?
  - Allow complete elimination of antibiotic residues
  - They have no side risks
  - They are affordable and sustainable

  - Answer: **They are affordable and sustainable**

Questions

- Can organs other than the liver metabolise drugs?
  - Only liver and brain
  - Only liver
  - Any biological tissue can metabolised drugs, but liver is major

  - Answer: **Any biological tissue can metabolised drugs, but liver is major**

Questions

- Do current methods allow complete degradation of antibiotics from wastewater?
  - Yes
  - No, only experimentally
  - No, there are no methods to degrade antibiotics

  - Answer: **No, only experimentally**

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Questions

- Would it be appropriate to combine methods for wastewater treatment in the future or would it be better

  to focus on one particular method?
  - Multiple methods will make wastewater treatment ineffective
  - It doesn´t matter, because wastewater treatent is worthless
  - Combining methods is the hope for the future

  - Answer: **Combining methods is the hope for the future**