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Overview of using Living and Non-living Microorganisms for the Removal of Heavy Metals from Wastewaters

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- **Abstract**: *The industries that generate large quantities of wastewaters containing heavy metals are in an increasing development. Sources of large fluxes of heavy metal wastewaters include electrical and electronic waste recycling, mining, electroplating and batteries, pesticides, pigments, dyes and textiles production. Hence, viable, environmentally-friendly, low-cost and efficient solutions are required in order to address this problem. Biomass-based removal methods represent a promising alternative to the conventional ones. The capacity of many biological materials for heavy metals removal from aqueous systems has been analyzed so far owing to the very good preliminary results obtained in related research studies. Microorganisms are very potent in this regard owing to their cells being highly adaptable to toxic environments. They have chemical structures with affinity to metals and the capacity to transform very toxic metal species into less harmful ones. The main processes that can be applied in wastewater treatment through the use of microbial organisms are biosorption for inactivated forms, bioaccumulation, biotransformation and biomineralization, respectively, for living forms. For these processes to be used successfully, different parameters such as pH, temperature, metal concentration and dosage of microbial biomass have been studied. The current paper gives an overview of the obtained lab-scale results of heavy metals removal from wastewater using both living and non-living microorganisms.*

• Introduction

Heavy metals are persistant pollutants that cause major problems to human health and damage to the environment due to their high levels.

According to the European Environment Agency (EEA), aquatic mediums are mainly contaminated with mercury, lead, cadmium and nickel.

Microalgae Bacteria Fungi

Conventional wastewater treatments are expensive and not effective enough in the removal of heavy metals.

Alternatives like the use of microorganisms as sorptive materials may be the long-term solution for the current issues.

• Comparison between Heavy Metals Removal Processes using Living and Non-living Microorganisms

Living microorganisms	Non-living microorganisms
- Uses active biomass in two main active processes (biosorption+bioaccumulation)	- Uses inactive biomass in one single passive process (only biosorption process)
- Slow process and low metal uptake (living cells are sensitive to high quantities of toxic metals)	- Rapid process, plus metal uptake is high (inactive cells have a stable chemistry)
- Nutrients for metabolic energy generation are constantly required	- No nutrients required and storage is very easy to maintain
- Possibility of regenaration and reuse is limited (the metals are integrated in the intracellular structures)	- Posibility to regenerate and reuse the biomass by desorption processes of the heavy metals
- Higher selectivity than biosorption, since the active metabolic processes can adapt to the pollutant	- Low selectivity, but can be enhanced through chemical treatment

• Influencing Parameters of Heavy Metals Removal using Living and Non-living Microorganisms

COMMON	pH of metal solution	Influences the metal ions chemistry
	metal solution concentration	Biosorbed metal per unit weight of biosorbent increases, while removal efficiency decreases
	other competing ions	Competing ions interfere with binding site and decrease removal efficiency of the targeted metal
	contact time	Identifying the optimum contact time will lead to saving time, energy and costs
	temperature	Identifying the optimum temperature can enhance the biosorption process and avoid biomass damage
SPECIFIC	cell concentration	In bioaccumulation process metal uptake will increase up to a certain limit of cell concentration
	adsorbent dosage	In biosorption process metal uptake will increase up to the limit of the adsorbent dosage

Case-study: biosorption results for priority metal pollutants using bacteria (*Bacillus* species)

Metal	Bacteria specie	Initial metal conc. (mg/L)	pH	Temperature (°C)	Adsorbent dosage (g/L)	Equilibrium time (h)
Hg(II)	*Bacillus licheniformis*	50	7	30	0.0005	1
Pb(II)	*Bacillus licheniformis*	200	6	20-22	0.7	12
Cd(II)	*Bacillus cereus*	200	6	35	-	20
Ni(II)	*Bacillus laterosporus*	10-20	7	30	40	2

• Conclusions

The numerous lab-scale studies have shown that microbial organisms (living and non-living) have a great potential to be applied successfully in large scale wastewater treatment. Upscaling analyses are now required.

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