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Microbial Simultaneous Eradication from Wastewater of Sulphate and Heavy Metals

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Abstract: Hazardous materials, heavy metals, and organic toxins released into the environment have caused considerable harm to microbes, plants, animals, and humans. Wastewater is one of the most contaminated ecosystems due to heavy metals emitted mostly by human activity. Bioremediation of wastewater is an ecologically acceptable and cost-effective method of removing heavy metals from sewage; the general purpose of this study is to analyse the dependability of anaerobic sludge biomass in removing sulfur compounds and heavy metals from waste water. The anaerobic sludge biomass evaluated in this work was taken from a wastewater treatment plant (WWTP) in Al-Rustumiya, Baghdad, and grown in the mineral medium for anaerobic growth. In serum bottles, batch metal removal tests were conducted concurrently with sulphate reduction. The biomass increased from the time of inoculation medium with 20 $mg \cdot L^{-1}$ (t = 0 day, MLVSS = 688 29 $mg \cdot L^{-1}$) to the 8th day, when it reached the highest value (MLVSS = 980 48 $mg \cdot L^{-1}$); more than 90% removal was observed for copper and nickel, almost 80% for lead and cadmium metals, and less than 80% removal for chrome and zinc. In addition, in the case of lead, copper, and nickel, sulphate removal was greater than 50%. Except zinc, all metals have the capacity to remove more than 60% of the COD.

Key words: Heavy metal, wastewater, anaerobic growth, sulphate, bioremediation.

Introduction

The emission of massive amounts of radioactive waste, heavy metals, and organic pollutants as a result of civilisational and technical growth has put growing pressure on the atmosphere and ecological system, causing catastrophic damage to the ecosystem (Corral-Bobadilla et al., 2019; García-Delgado et al., 2015). Compounds and extremely dangerous elements, such as toxic metal contaminants, have become increasingly important to manage and have garnered considerable attention in the previous two decades (Budzyńska et al., 2022). However, one of the most pressing issues in recent years has been the treatment of sewage water. These types of effluents and solids include large concentrations of heavy metals such as Al, Pb, Mn, Cr, Zn, Ni, Co, and Cu and other substances, which are mostly the product of numerous industrial processes. Heavy metal contamination from wastewater irrigation and sludge treatments has posed a severe danger to the environment (Ngodhe and Odhiambo, 2018). Nonetheless, several toxic metals deplete the micronutrients in living creatures; they have the ability to be hazardous to live species if utilised in greater

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quantities than necessary (Engwa et al., 2019). Heavy metal ions have been removed from industrial waste water using chemical precipitation, ion exchange, evaporative recovery, electrochemical treatment, filtration, adsorption and membrane technologies, as well as any other traditional methods. These methods, however, may be unsuccessful or costly (Azimi et al., 2017). The majority of them need significant financial investment. As a result, their employment is limited when economic considerations outweigh the significance of pollution management (Selvi et al., 2019).

Bioremediation is an eco-friendly and economical solution to removing pollutants as opposed to traditional physical and chemical treatments, which are usually very costly, Cost-effectively, preserving ecological harmony and re-creating natural settings make them eligible for treatment organically by encouraging atmosphere development since bacteria make it easier for hazardous metals to bind with sulphur and be removed from anaerobic situations with low pH; particularly for little metal amounts. As well as, existing processes produce an important amount of toxic sludge (Shao et al., 2010). Heavy metal biosorption is a bio-technique that has been touted as a viable alternative to traditional physicochemical methods (Atlas et al., 1993). The United States Environmental Protection Agency (USEPA) defines bioremediation as a treatment technology that uses biomaterials to decrease the amount of pollutant as well as toxicity. Bacteria, various algae, fungi, and industrial and agricultural wastes, in addition to other biopolymer materials, are used as metal-removal biosorbents. Most biomaterials or natural products have proven good biosorption capabilities for a wide spectrum of pollutants in general (Latif and Mahmood, 2018; Azimi et al., 2017; Kelly and Wood, 2000). This data leads to the ultimate purpose of this study: Analyse the dependability of anaerobic sludge biomass in removing sulphur compounds and heavy metals from waste water. If the bacteria can be successfully grown, a wide range of organisations will profit (Jameel, 2022). Harnessing the sulphur-reducing capability of these bacteria will help a variety of initiatives, from the landfill to the water treatment facility. As a consequence, this study is to investigate the viability of utilising sulfate reduction bacteria as a consequence, the goal of this study is to investigate the sewage sludge in the waters of the Al-Rustumiya treatment plan.

Materials and Methods

Biomass of Anaerobic Sludge and its Growing Conditions

The anaerobic sludge biomass used in this investigation came from a wastewater treatment plant (WWTP) in Al-Rustumiya, Baghdad. Mineral Medium (g/L) contained the following ingredients for anaerobic biomass growth: 0.5 (KH_2PO_4), 1 (NH_4Cl), 1.323 (Na_2SO_4), 0.1 ($CaCl_2$), 0.1 (ascorbic acid), 0.3 (sodium citrate), 0.289 ($FeSO_4$•$7H_2O$), and 1 (yeast extract). 1N NaOH was used to adjust the pH of the solution to 7. 10% w/v; the aspirator container containing the collected anaerobic biomass was filled with 1 L As a carbon source, 60% v/v sodium lactate was used in the pH-adjusted medium. During inoculation, the bottle was purged with nitrogen gas, and it was cultured at 30°C for 7 days.

Batch Metal Removal Experiments

Studies on sulphate, as well as heavy metal removal, were carried out concurrently in 0.1 L serum vials equipped with a rubber stopper and aluminum crimp closures. $CuCl_2{\cdot}2H_2O$, $Cd(NO_3)_2{\cdot}4H_2O$, $NiCl_2{\cdot}6H_2O$, $FeCl_3{\cdot}6H_20$, $PbNO_3$, and $ZnCl_2$ were used to make individual metal stock solutions of 10,000 mg/L of Cu, Pb, Ni, Cd, Zn and Fe. Individual metal-containing stock solutions were combined with serum vials containing the aforementioned medium and sodium lactate, yielding final metal concentrations of 20 and 100 $mg{\cdot}L^{-1}$. Before and after inoculation with 20% v/v biomass, the bottles were purged with N_2 gas, as before, the bottles were then incubated at 30°C to track metal elimination. In the trials, a medium with no metal and simply, as a control, carbon source and biomass were used. At regular intervals, conductivity, pH, sulphate, COD, metals, MLVSS (mixed liquid volatile suspended solids), concentrations, and sulphide were measured. Samples were extracted on a regular basis using a disposable syringe and a disposable needle. All of these batch tests were carried out in duplicate.

Analytical Techniques

Sulphate was analysed using the turbidimetric tool, COD was located by using the reflux method (Bhatt et al., 2020), biomass was calculated as MLVSS according to Salman et al. (2022), and metal concentration in the supernatant was located by using (atomic absorption spectrometer; AA240, Varian, The Netherlands) according to Mouhamad et al. (2017). Depending on the procedure published by Cord Rowish; sulfide concentration was determined in the samples (Hasan and Taleb, 2020).

Results and Discussions

Nickel, lead, cadmium, chrome, copper, zinc, lead and cadmium, biomass outgrowth in addition to COD reduction and sulfate of anaerobic sludge biomass were examined. Figure 1 depicts the biomass development stage in the presence of heavy metals at final concentrations of 20 mg·L^{-1} and 100 mg·L^{-1}, respectively. The biomass concentration increased significantly from the moment of inoculation (t = 0 day, MLVSS = 688 29 mg·L^{-1}) to the 8th day when it reached a maximum value (MLVSS = 980 48 mg·L^{-1}). The concentration of biomass thereafter began to drop (t = 12th day, MLVSS = 528 38 mg·L^{-1}). The data presented above are consistent with the control biomass. The biomass increased well at 20 mg·L^{-1} metal concentration compared to 100 mg·L^{-1} metal concentrations, demonstrating a considerable inhibitory impact of these metals at high final concentrations in the medium. revealing that high metal concentrations have a potent toxin that inhibits cell growth and cell wall activity because they can exchange for major ions that are used for cellular fabric growth and deny functional groups of macromolecules, increase harm to the safety of the cellular membrane and disable cellular enzymes,

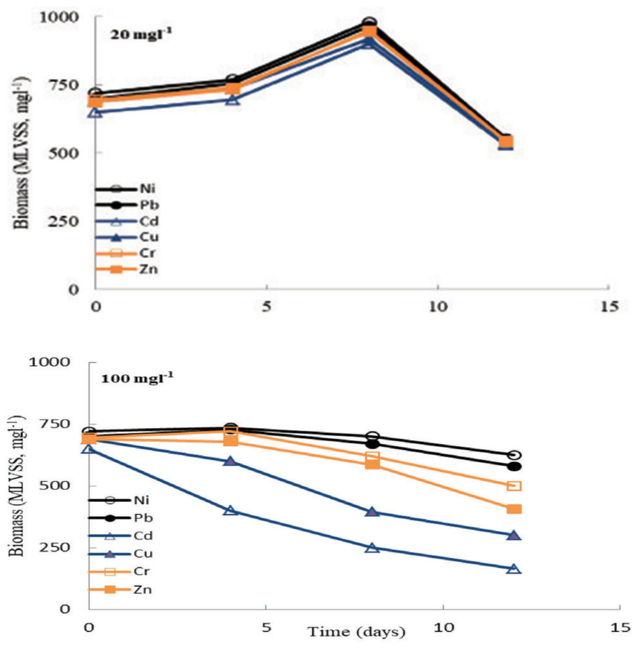

Figure 1: Growth achievement of anaerobic sludge biomass in the existence of heavy metals at various final concentrations, 20 and 100 mg·L.

and inhibit the growth of microbial populations and their ability to adsorb elements. In this study, Cr^{+2} and Zn^{+} were shown to be more inhibitive of biomass development than the other metals. The effect of Cd^{+} and Cr^{+2} on microbial development is mainly attributed to their negative effects on the biomass's capacity to synthesise protein (Luciene et al., 2015).

Figure 2 depicts the removal efficiency of heavy metals at a concentration of 20 mg·L^{-1}. More than 90% removal was achieved with copper and nickel, and more than 80% with lead and cadmium metals, with the exception of chrome and zinc, which exhibited a slightly lower removal of 80%. In comparison to these results, the mineral removal values at final heavy metal concentrations were lower. The removal effectiveness of metals at 100 mg·L^{-1}starting concentration is shown in Figure 2. In terms of lead, nickel, and copper, more than 65% of elimination was obtained. Chrome zinc was removed at a rate of more than 50%, while cadmium was removed at a rate of 44%.

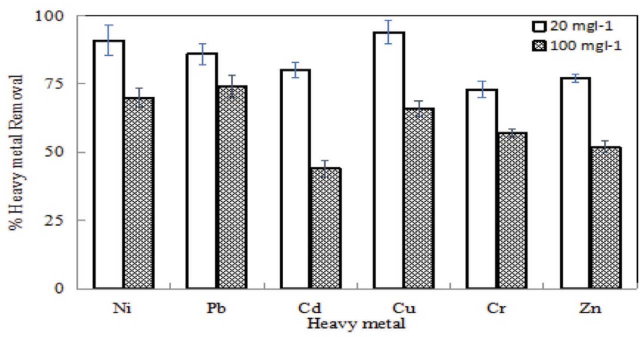

Figure 2: Removal of heavy minerals using the anaerobic sewage biomass with various heavy metals concentrations.

The inhibitory levels for the Cu^{+2} removal extent by strain NT^{-1} showed a clear decrease trend as the Cu^{+2} concentration in the system steadily rose. Cu^{+2} removal is the amount to which NT^{-1} is achieved. When Cu^{+2} is present, the percentage increases to more than 20%. Concentrations were in the range of 100–300 mg·L^{-1}. When the Cu^{+2} concentration was more than 300 mg·L^{-1}, the amount of Cu^{+2} removals by NT^{-1} was reduced by less than 8% (Tu et al., 2018).

Figure 3 depicts the sulphate shorthand results with two different final concentrations of COD elimination by metals for concentrations of 20 mg·L^{-1}, lead, copper, and nickel removed more than 50% of the sulphate, whereas cadmium, chromium, and zinc removed less than 50% of the sulphide. Except for cadmium, chromium, and zinc, which resulted in less than 40% sulphate removal at 100 mg·L^{-1} starting metal concentration, all of these metals demonstrated about 40% sulfate removal. Among the metals investigated, Ni+ and Pb+2 had the highest sulfate removal rates of 56% and 58%, respectively (Figure 3), indicating a less inhibitory influence on the biomass for sulphate reduction. In general, these sulphate reduction values are also poor when compared to those published in the literature, most likely due to the anaerobic sludge biomass employed not being acclimatised for the sulphate reduction process. Sulphate removal was reduced in the presence of 100 $mg{\cdot}L^{-1}$ metal level compared to 20 $mg{\cdot}L^{-1}$ starting metal concentration (Figure 3). This pattern can be explained by a decrease in the metabolic activity of the bacteria in the biomass caused by metal toxicity (Springthorpe et al., 2019). Sulphate-reducing bacteria (SRB) make it easier to turn sulphate into sulphide, and when heavy metals combine with the sulphides, hazardous metals precipitate as metal sulphide (Ayangbenro et al., 2018; Azizi et al., 2016; Mouhamad et al., 2017, 2018).

The results demonstrate the influence of several metals on COD elimination. In the presence of COD, more than 60% of the COD was removed. 20 mg/L from all metals, except zinc, where the rate was less than 50% (Figure 4). COD elimination in the presence of a 100 $mg{\cdot}L^{-1}$ starting concentration was sandwiched between

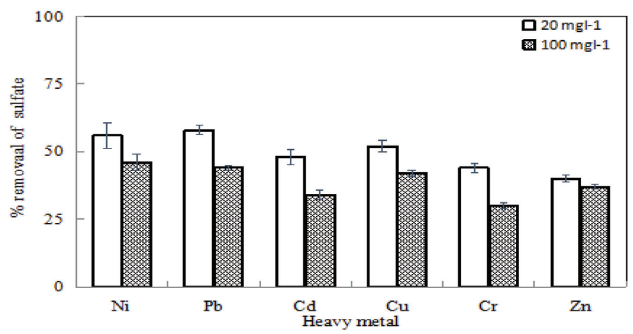

Figure 3: Sulphate elimination by the anaerobic sewage biomass at various heavy metals concentrations.

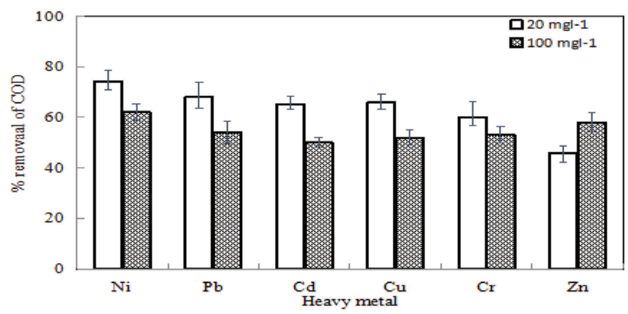

Figure 4: COD elimination by the anaerobic sewage biomass at various heavy metals concentrations.

52 and 62 percent, with the lowest being to cadmium (Barnes et al., 1991; Kiran et al., 2017; Kumar et al., 2020; Kumar and Pakshirajan, 2021).

The results of sulphate elimination were similar to those of COD removal by the presence of metals in biomass at starting concentrations of 20 $mg{\cdot}L^{-1}$ and 100 $mg{\cdot}L^{-1}$. However, the COD removal data show that metals at lower concentrations stimulate microbial activity to consume more COD for growth than metals at higher starting concentrations (Figure 4), as previously stated. While above this strength, the effectiveness of the treatment should be significantly impacted. Average organic reduction is lower than the system's tolerance limits for heavy metals, as measured by chemical oxygen demand (COD) (Geets et al., 2006; van den Brand et al., 2015; Liu et al., 2022; Luciene et al., 2015; Sun et al., 2018).

Conclusions

The anaerobic sewage biomass collected from a local sanitation treatment plant (Al-Rustumiya) in south Baghdad revealed very high removal of various metals at a low starting concentration of 20 $mg{\cdot}L^{-1}$ (nickel, lead, cadmium, copper, chromium, and zinc). The heavy metal removal technique was named after the biomass's ability to convert sulfate to sulfide, causing metals to precipitate in the process. At a high beginning concentration of the elements, the activity of the biomass, including its growth, sulphide and COD reduction, was restrained, resulting in a decreased elimination of these components of 100 $mg{\cdot}L^{-1}$. The experiment revealed the possibility of removing heavy metals from sulphate-rich sewage water using anaerobic sludge biomass.

Furthermore, new research on heavy metal dynamics and modeling is necessary to further demonstrate its potential; identify the most effective techniques for minimising fine pollution. In reaction to micro-features, pollution is a relatively new concern with long-term water quality. As a result, we create a new framework that combines both. The breadth of the problem, the sources of the problem, its impacts, and its sustainability; the long-term, cross-sectoral, and multilevel aspects to picking which policy to implement Furthermore, these animals can live in temperatures ranging from 5°C to 75°C. Temperature influences the rate of microbial processes; as temperatures fall, so do microbial processes.

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