Research Article

Dead biomass of *Morganella morganii* acts as an efficient adsorbent to remove Pb(II) from aqueous solution in different aeration–agitation and pH conditions

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Abstract
Lead (Pb) removal from industrial effluent using physicochemical methods, though efficient, poses economic and environmental challenges due to high cost and generation of toxic wastes as by-products. Biosorption using dead microbial biomass, on the other hand, offers economic feasibility and environmental safety, but its application is limited because it relies on specific pH and agitation conditions. To address these issues, we used wastewater of a drain containing effluent from nineteen industries and isolated Pb-tolerant strains of *Morganella morganii* (ND1 and ND2). We demonstrated that the dead biomass of *M. morganii* ND1 and ND2 maintains a high biosorption potential at pH ranging from 3 to 5 in both shaking (89.96–89.99 mg/g) and static conditions (89.99–84.05 mg/g). Adsorption of Pb(II) from *M. morganii* ND1 and ND2 follows pseudo-second-order kinetic model and chemisorption as a dominant underlying mechanism in aqueous media. Fourier-transform infrared spectroscopic analyses of dead biomass before and after Pb(II) biosorption revealed the involvement of phosphoryl, hydroxyl, amide, carbonyl, and phosphate functional groups during biosorption. We demonstrated the potential of *M. morganii* ND1 and ND2 in developing a cost-effective biosorption technology for removing Pb in industrially relevant pH, and both agitation and static conditions.

Keywords Bioremediation · Heavy metal pollution · Industrial effluent · Environmental application

1 Introduction

Lead (Pb), a key heavy metal in the history of civilization and economic development, gained significance as a driver of development and concern of public health in the fastest growing economies of today [1, 2]. Though Pb occurs naturally, anthropogenic activities, such as mining and other industrial operations, contribute significantly to its global cycling. Developing countries rely on Pb for acid batteries (electric vehicle, mobile, and household electronic equipment), infrastructure development (roofing and gutters), electroplating, pigments, and ammunition. With an estimated worth of \$75 billion by 2024, the battery industry alone uses ~85% of global Pb demand and serves as the primary source of Pb pollution in the environment [3, 4]. Being mutagenic and carcinogenic, Pb ranks second in the US ATSDR "Priority List of Hazardous Substances 2017" [5]. At any level, Pb is considered unsafe to humans; for example, USEPA and World Health Organization (WHO) formulated the permissible limits of Pb in drinking water as low as 0.015 mg/l and 0.01 mg/l, respectively [6, 7].

Though children and pregnant women form the most vulnerable groups, Pb remains toxic to both the genders of all age groups. Pb accumulates in the body after long-term exposure and damages nervous, cardiovascular, renal, gastrointestinal, and hematologic systems in humans [3, 8,

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