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Myxococcus xanthus and its potential for biosorption of heavy metals

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Abstract
In the last decades, the heavy metal contamination got a great deal of concern and has become a major public health risk particularly in the developing countries as the toxicological manifestations induced by their exposure are well known and clear in animals and human beings. For their removal from environment, the conventional remediation strategies are either expensive/led to the generation of high volume of toxic by-products into the surrounding environment. Thus, the need of eco-friendly removal technique has motivated the researchers towards the use of biological techniques for their removal and one of them is biosorption. Therefore, the present work has been designed to document the heavy metal removal efficiency of a unique bacterium *i.e. Myxococcus xanthus* which is rich in extracellular polysaccharide (EPS). It is a predatory, soil dwelling myxobacterium and experimental model to study the social behavior of bacteria.

Keywords: biosorption, heavy metals, *Myxococcus xanthus,* removal strategies

1. Introduction

There are many organic and inorganic compounds that are causing environmental pollution especially heavy metals. Generally, heavy metals are defined as the elements whose density exceeds 5 g/cm^3, atomic weight range from 63.5 to 200.6 a.m.u. (Srivastava *et al.*, 2008) [1] and a large number of elements fall into the category of heavy metals. There are various strategies for the removal of heavy metal like physical, chemical and biological. From these the use of microorganisms for the removal of heavy metals was well reported by many researchers. Sakaguchi *et al.*, 1979 [2] reported that the dead cells (bacteria, fungi, algae *etc.*) could accumulate heavy metals to the similar/greater extent than that of living ones but earlier most of the studies were limited to the use of fresh water/marine water algae as biosorbent for the removal of heavy metals. Later in 1980s, the researchers had started the use of other microorganism for the biosorption. There are various other techniques that have been employed for the treatment of heavy metal like precipitation and electrochemical technologies *etc*. but these are not economic as well as eco-friendly. While, the biosorption has many advantages like low use of biosorbent, no release of toxic compounds into the environment and short operation duration. Biosorption is a physiochemical process and is defined as the potential of biological materials to accumulate heavy metals from waste water (Volesky *et al.,* 1990; Fard *et al.,* 2011) [3, 4]. It is a metabolically passive process and the capacity of biosorbent for the removal of contaminants depends on kinetic equilibrium, composition of the sorbents and cellular surface (Velásquez *et al.,* 2009) [5]. It is also depends upon the type of biosorbent biomass whether living /dead, pH, metal ion concentration *etc.* while, the temperature does not play significant role in the range of 20-35ºC (Aksu *et al.,* 1992) [6]. The most effecting factor is pH as it influences chemistry of metal and the activities of functional group in the biomass (Galun *et al.,* 1987) [7]. Different removal strategies of heavy metals are shown in Figure 1. Generally, in terms of environmental remediation technique the biosorption is more preferable to other techniques like bioaccumulation because of faster rate and higher removal efficiency. Moreover, in biosorption the metals are bound to the cellular surface which is a reversible process whereas bioaccumulation is partially reversible.

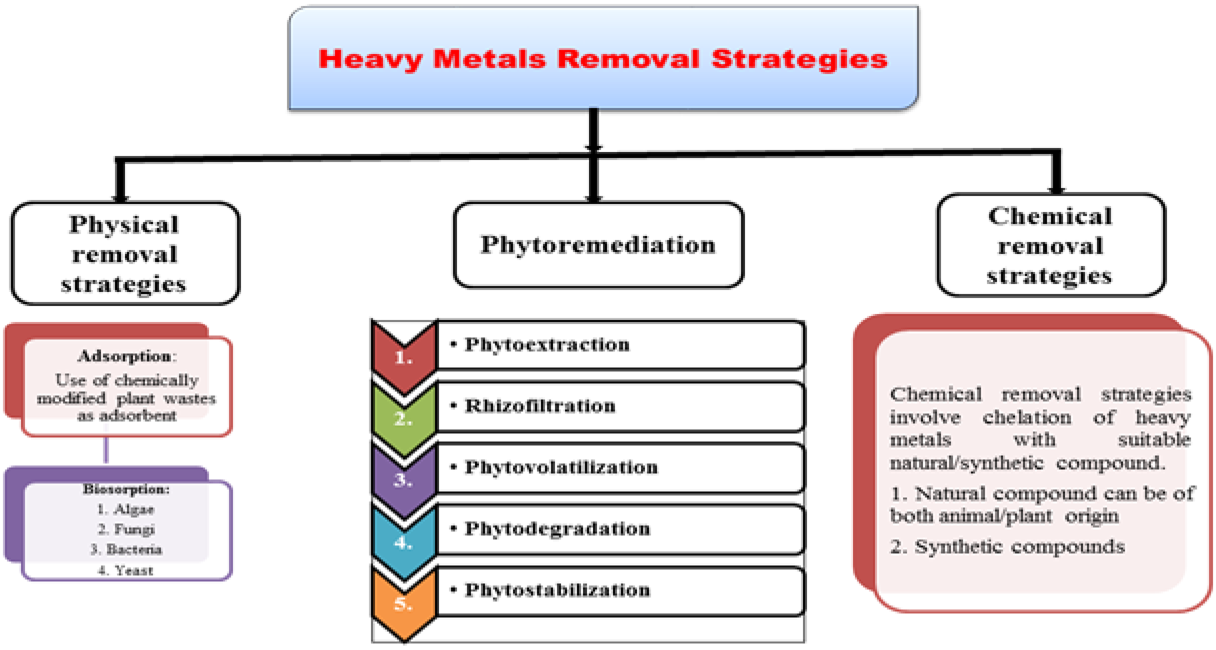

Fig 1: Different strategies of for heavy metals removal from the environment

2. Characteristics of *M. xanthus* and its biosorption potential of heavy metals

In the last decades, *M. xanthus* myxobacterium was used as biosorbent for the removal of heavy metals like Pb, Ag, Ur, La, Co, Mn, Zn, Cd, Cr *etc. M. xanthus* is well known for remarkable morphogenesis and differentiation (Gonzalez-Munoz *et al.,* 1997) [8]. Myxobacteria have received a great deal of interest because of their various unique characteristics like multicellular life cycle (Whitworth, 2008) [9], co-operative predation, exhibition of communal responses under starvation conditions, fruiting body formation and collective sporulation (Kaiser *et al.,* 2010) [10]. The cooperation and multicellular behavior are not shown under favorable conditions by the bacterium (Muñoz-dorado *et al.,* 2016) [11]. During these activities *M. xanthus* exchange their outer membrane (OM) components. It lyses a variety of microorganisms (both gram negative and gram positive bacteria) in non-species-specific manner and can grow using the products released during prey lysis as its sole nutrition source (Mendes-Soares *et al.,* 2013) [12]. It was reported that the lysis is performed by *M. xanthus* like other gram negative bacteria mediated through the production of outer membrane vesicles (OMVs). Structurally, OMVs are roughly spherical membrane-bounded structures (Kulp *et al.,* 2010; Whitworth, 2011; Kaur *et al.,* 2017) [13, 14, 15]. *M. xanthus* is a predatory member of soil microbial community. The life cycle of *M. xanthus* is very complex represented in Figure 2.a. It lacks flagella therefore show no movement in liquid medium but mobile on solid nutrient medium. The cells of *M. xanthus* are organized in biofilm consists of series of layers. The organization of cells results into swarms. After swarms formation all numerous bacteria cooperate to produce digestive enzymes and antibiotics for the predation of other microorganism. For predation direct contact with the prey is required as shown in Figure 2.b. (Zusman *et al.,* 2007) [16]. During predation the mycobacterium encounters the prey cell and fuses either or releases the content of OMVs near of foreign cell. OMVs secrete secondary metabolites for the lysis of prey cell. The detailed structure of OMVs is also shown Figure 2.b.

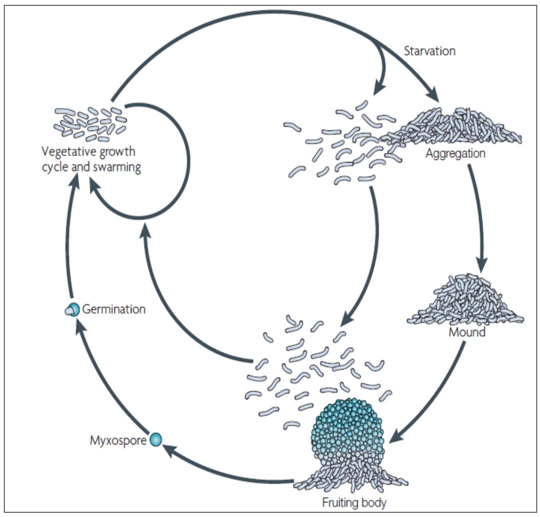

Fig 2(a): Life cycle (Adopted from Zusman *et al.,* 2007) [15]

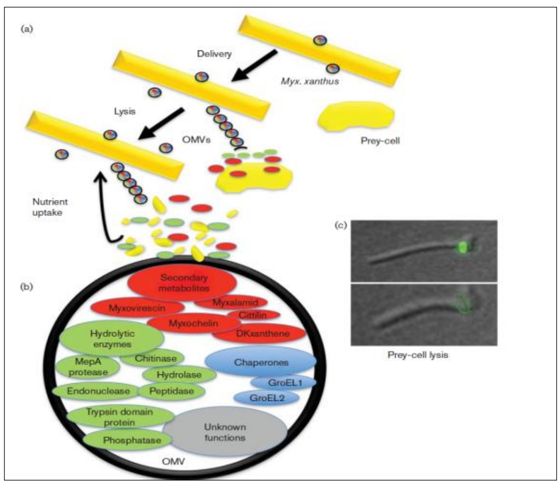

Fig 2(b): Mechanism of prey-cell lysis (contact-dependent mechanism) (Adopted from Kaene *et al.,* 2016) [17].

The biosorption of Uranium using *M. xanthium* as biosorbent was observed up to 2.4 mM uranium/g dry weight and the reaction was relatively rapid that it attained equilibrium within 5-10 minutes. The maximum uptake was observed at pH 4.5. The biosorbed Uranium was recovered up to 80.82% using sodium carbonate as desorbent agent (Gonzalez-Munoz *et al.*, 1997) [8]. It was observed that the use of dead cell biomass of bacterium could be of great interest because of low cost and recovery percentage as the heavy metals are located on cell wall or within the extracellular mucopolysaccharide of myxobacterium. Omar *et al.*, 1997 [18] analyzed the potential of brewery yeast and *M. xanthus* for the removal of various heavy metals and they revealed that the biomass of myxobacterium was much more suitable for the removal purpose. The desorbent agent used was sodium carbonate which enabled the recovery of UO_2^{2+} up to 94.53% from the both biosorbent. They revealed that the higher potential of *M. xanthus* for the removal of heavy metals was because of the presence of high amount of EPS. The strain used for the biosorption of lead (Pb) was *M. xanthus* 422. For this the cell were grown in liquid cultures containing CT broth and kept at 28ºC at 200 rpm for 24, 48, 66 and 72h. The resultants were divided into three batches: batch 1 contained cell with EPS, batch 2 cells without EPS and batch 3 only EPS. For dry biomass, wet biomass was dried at 120ºC for 24 h, ground in pestle and mortar and then used as biosorbent. Dry biomass accumulated 1.28 mmol of lead/g and was declared as more efficient than wet biomass. Sodium citrate was used as desorbent agent and the recovery was 92.17%. The lead accumulation was observed on cell wall and EPS of bacterium (Omar *et al*., 1998) [19]. The silver (Ag) sorption using *M. xanthus* was studied by Merroun *et al*., (2001) [20]. The accumulation percentage of Ag ranged from 8.12-75% of the total Ag present in solution. The pH for sorption study was 5.5 to avoid the precipitation of Ag and the desorption solution of ammonia with 2 M concentration enabled the recovery of Ag up to 78%. Merroun *et al.*, (2003)[21] analyzed the potential of *M. xanthus* for the accumulation of Lanthanum (La) which was observed up to 0.6 mmol/g wet weight and 0.99 mmol/g dry weight. Transmission electron microscope (TEM) studies revealed that the considerable amount of La cation was fixed in EPS, in cell wall and a little in the cytoplasm.

3. Conclusion

The use of *M. xanthus* as a biosorbent for the removal of heavy metal from waste water was well reported by few researchers and they revealed that it has good potential for the same because of the large amount of EPS. But these studied are limited as this bacterium is very unique in different aspects than other prokaryotes. The uniqueness of bacterium has led the researchers to carry out the studies on its life cycle complexities, predation, cheating behavior, biotechnological aspects and application *etc.*

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