Biosorption of Lead (Pb^{2+}) from Industrial Effluent using Green Algae

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Abstract: ***Heavy metal pollution is one of the most serious environmental problems being faced by the world today. Biosorption has emerged as a cost-effective and efficient alternative technology for removal of heavy metals. The potential of three immobilized algae species for removal of Lead (Pb^{2+}) from industrial effluent was analysed through batch studies. Algal bloom water samples were obtained from fish ponds in Prof. Olu Odeyemi's Farm, Ilesa. Effluent was collected from industrial discharge system around Ile–Ife (Nigeria). Algae were isolated from the effluent samples using pour plate technique on Allen and Bristol agar media at pH 7.1. The identity of the algae isolates was established using Identification guide to Freshwater and Terrestrial algae. Algae were immobilized with 1.5% calcium alginate and the beads of approximately 3mm were formed using peristaltic pump. Biosorption batch studies was carried out by the addition of 150 beads into 100ml solution (50 ml of wastewater and 50 ml of media) in 250ml conical flask at 100rpm, room temperature and pH 3, 5 and 7. Concentration of Lead (Pb^{2+}) was determined in 2 days interval using atomic absorption spectrophotometer at 0.04mg/l detection limit. The algal isolates were identified asSynochromonaselaeochrus, Scenedesmusfacatuschodat and Aphanizomenonflos-aquae. The percentage removal of Lead (Pb^{2+})by Synochromonaselaeochrus, Scenedesmusfacatuschodat and Aphanizomenonflos-aquae varies with pH and time. At pH 5, Synochromonaselaeochrushad the best percentage removal rate (100%) (that is not detectable in the effluent)while Scenedesmusfacatuschodatand Aphanizomenonflos-aquae performed best at (100%) pH 3 and 5 over the period of time.At pH 7, the percentage removal of Lead (Pb^{2+})decreases with time for all algae species. At pH 3, Scenedesmusfacatuschodatand Aphanizomenonflos-aquae performed better by complete (100%) removal of Lead (Pb^{2+})starting from day 1 while Synochromonaselaeochrus completely (100%) remove Lead (Pb^{2+})starting from day 3. Since the algae isolates showed appreciable sorption of the metal, they can be used for biosorption of metals from industrial effluentprior to its discharge to avoid environmental pollution.***

Keywords: Biosorption, Synochromonaselaeochrus, immobilization, Industrial effluent, Lead (Pb^{2+})

1. Introduction

Heavy metal removal from aqueous solutions is an important issue faced by industries discharging waste water containing heavy metals. Thousands of tons of heavy metals are discharged from industrial processes such as electroplating, plastics manufacturing, mining and metallurgical processes. A number of physicochemical methods, such as chemical precipitation, adsorption, solvent extraction, ion exchange, membrane separation, etc., have been commonly employed for stripping toxic metals from wastewaters [1]. However, these methods have several disadvantages, such as incomplete metal removal, expensive equipment and monitoring system requirements, high reagent or energy requirements and generation of toxic sludge or other waste products that require disposal. Furthermore, they may be ineffective or extremely expensive when metal concentration in wastewater is in the range 10-100 mg l^{-1}[2]

Biosorption of heavy metals from aqueous effluents is a process that has proven very promising. The major advantages of biosorption technology are its effectiveness in reducing the concentration of heavy metal ions to very low levels. The major advantages of biosorption over conventional treatment methods include: low cost, high efficiency, minimization of chemical and/or biological sludge regeneration of biosorbent, no additional nutrient requirement, and the possibility of metal recovery [3].

One of the main interests for microalgae is focused on their use for heavy metal removal from effluents. Efforts have been made to test the efficacy of immobilized algae and cyanobacteria for the removal of heavy metals from aqueous solution. Immobilization is a general term that describes many different forms of cell attachment or entrapment [4]. Various techniques, such as flocculation, adsorption on surfaces, covalent binding to carriers, crosslinking of cells, encapsulation in polymer gel and entrapment in polymeric matrix, are used for cell or biomass immobilization. Immobilization generally tends to increase more metal accumulation by biomass. Size of the immobilized beads is a crucial factor for use of immobilized biomass in biosorption. More than 15 microalgal species have been already studied for their potential in heavy metal removal [5].Chlorella salina cells immobilized in alginate were used to remove Co, Zn, and Mn heavy metals [6]. Chlorella vulgaris beads more efficient in heavy metal removal from sewage than free cells. The efficiency in Iron, Nickel, and Zinc removal was higher in the immobilized cells than free cells by 27, 23 and 25% respectively [7].

Objective of the study was to analyse the potential of immobilized algae(in alginate) for removal of Lead (Pb^{2+})from industrial effluent through batch studies.

2. Materials and Methods

2.1 Materials

Algal bloom water samples were obtained from eleven fish ponds in Prof. OluOdeyemi's Farm, Ilesa, Osun State (Nigeria). Wastewater (effluent) was collected from industrial discharge system around Ile–Ife, Osun State (Nigeria). Agar agar (Oxoid) was purchased from Sigma Aldrich and other chemicals used were of analytical grade.

2.2. Methods

2.2.1. Apparatus

Glass-ware were thoroughly washed with detergent and rinsed with distilled water. They were air-dried, wrapped in aluminium foil and then sterilized in hot air oven at 180°C for 3 hours, in canisters.

2.2.2. Culture Media

Allen and Bristol media used were prepared in accordance with the manufacturers' specification. The pH of the media was adjusted to pH 7.1, homogenized and thereafter sterilized by autoclaving at 121°C for 15mins. The media were allowed to cool down to about 45°C before use.

2.2.3. Algae Isolates

Algae were isolated from algal bloom water sample by serial dilution and pour plate technique on Allen and Bristol agar. The plates were inverted and incubated for about 1 week under steady illumination at room temperature. After incubation period, isolated colonies were selected, carefully picked with a sterile inoculating needle and then re-suspended in sterile Allen and Bristol broth media. The flasks were incubated for about 1 week under steady illumination at room temperature inside a laminar flow hood. From this, a drop was taken and placed on a glass slide, covered with cover slip and then observed under light microscope with X40 objective for observation of morphology and size of the algal sample. Several observations were done for each flask to ensure pure culture. The shape, morphology and possible extracellular structures observed were compared with those documented in Identification guide to Freshwater and Terrestrial algae [8]. Biomass was then harvested by filtration, washed with generous amounts of deionized water, resuspended and washed again. The pure algae isolates were concentrated by allowing the algae to settle for 30min and then decant the supernatant. A mixed culture flask was further purified by serial dilution and pour plate technique.

2.2.4. Immobilization of algae with Calcium alginate

Sodium alginate solution (3%) was prepared by the addition of 3g of sodium alginate powder in 100ml of pure distilled water. Calcium chloride solution (2%) was prepared by adding 4g of calcium chloridedihydrate powder in 100ml of pure distilled water. The two solutions were autoclaved for 15mins at 121°C. After the solutions were cooled to room temperature, 100ml of the concentrated algae culture was added to the sodium alginate solution and mixed well. A burette of algae/alginate mixture was clamped above a beaker of calcium chloride solution. The algae/alginate mixture was allowed to drip through and form beads in the beaker while the beaker was gently swirled.The beads were allowed to harden for few minutes before straining them out of the beaker. The beads were rinsed with sterile distilled water and then kept in a stoppered bottle of distilled water in the refrigerator. The beads were approximately 3mm in diameter. Blank beads were prepared without adding the culture.

2.2.5. Batch Studies

The batch adsorption studies were carried out in 250ml Erlenmeyer flasks at room temperature. Experiments were conducted for different pH conditions (3, 5 and 7) and known initial concentration of Zinc (Zn^{2+}) and Iron (Fe^{2+}) in the industrial wastewater. The flasks were placed in orbital shaker with continuous shaking at 100rpm at room temperature. 150 beads were counted (Blank and Algal beads/cubes) and mixed with 100 ml solution in 250ml conical flask. The 100ml solution contains 50ml of wastewater and 50ml of media. At regular intervals (once in 2 days) 3ml of sample was taken and concentration of Lead (Pb^{2+})was checked using atomic absorption spectrophotometer at 0.04mg/l detection limit.

2.2.6. Sample Digestion and Analysis

Sample digestion was carried out according to standard analytical methods using Nitric acid (HNO3), Hydrochloric acid (HCl) and Sulphuric acid (H_2SO_4) at relatively low temperature as reported by[9] and [10]. For the analysis, Atomic Absorption Spectrophotometer (PyeUnicam Model) was calibrated with standard solutions and the digested sample was analyzed for the presence and concentration ofLead (Pb^{2+})at 0.04mg/ldetection limit. The percentageof heavy metal removed was calculated as:

$$\%\ heavy\ metal\ removal = \frac{Initial\ heavy\ metal\ conc - Final\ heavy\ metal\ conc}{Initial\ heavy\ metal\ concentration} X\ 100$$

3. Results

The ability of *Synochromonaselaeochrus, Scenedesmusfacatuschodat* and *Aphanizomenonflos-aquae* (Fig. 1, 2 and 3) to remove Lead (Pb^{2+}) from an industrial effluent was studied. The initial concentration of Lead (Pb^{2+}) in the effluent was 0.43ppm. At this heavy metal detection limit, the results indicated that the Lead (Pb^{2+}) was removed by these algae species. The percentage removal of Lead (Pb^{2+})by *Synochromonaselaeochrus, Scenedesmusfacatuschodat* and *Aphanizomenonflos-aquae* varies with pH and time. At pH 5, *Synochromonaselaeochrus* had the best percentage removal rate while *Scenedesmusfacatuschodat* and *Aphanizomenonflos-aquae* performed best at pH 3 and 5(Fig. 4 to 6).At pH 7, the percentage removal of Lead (Pb^{2+}) decreases with time for all algae species (Fig. 4 to 6). At pH 3, *Scenedesmusfacatuschodat*and *Aphanizomenonflos-aquae* performed better by complete (100%) removal of Lead (Pb^{2+})starting from day 1 while *Synochromonaselaeochrus* completely (100%) remove Lead (Pb^{2+})starting from day 3 (Fig. 7).

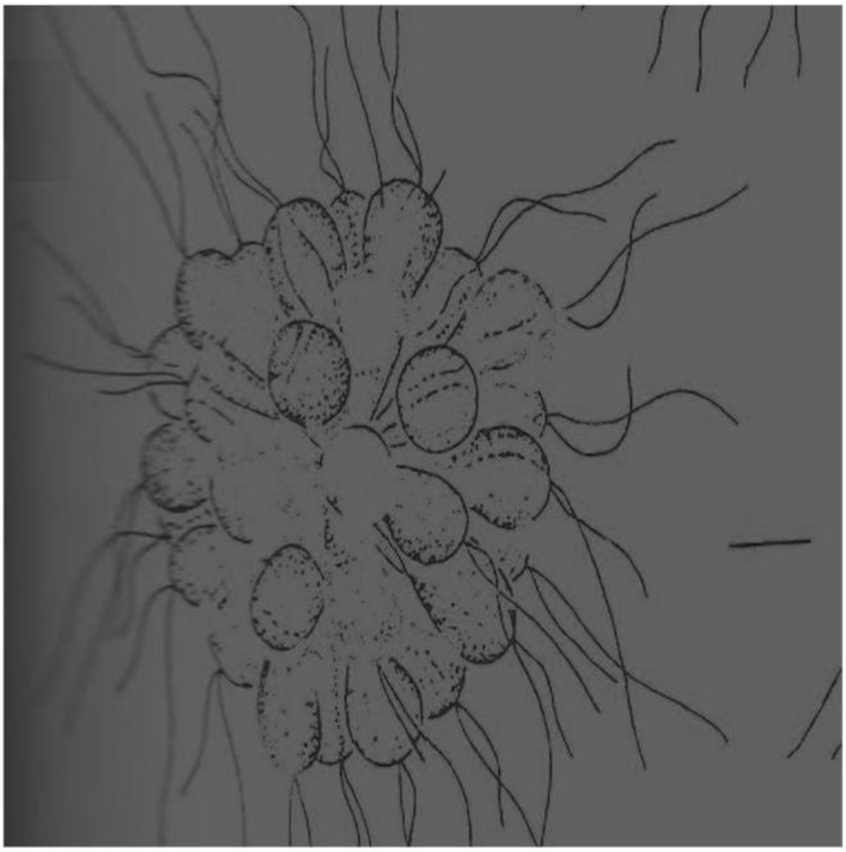

Figure 1: *Synochromonaselaeochrus*

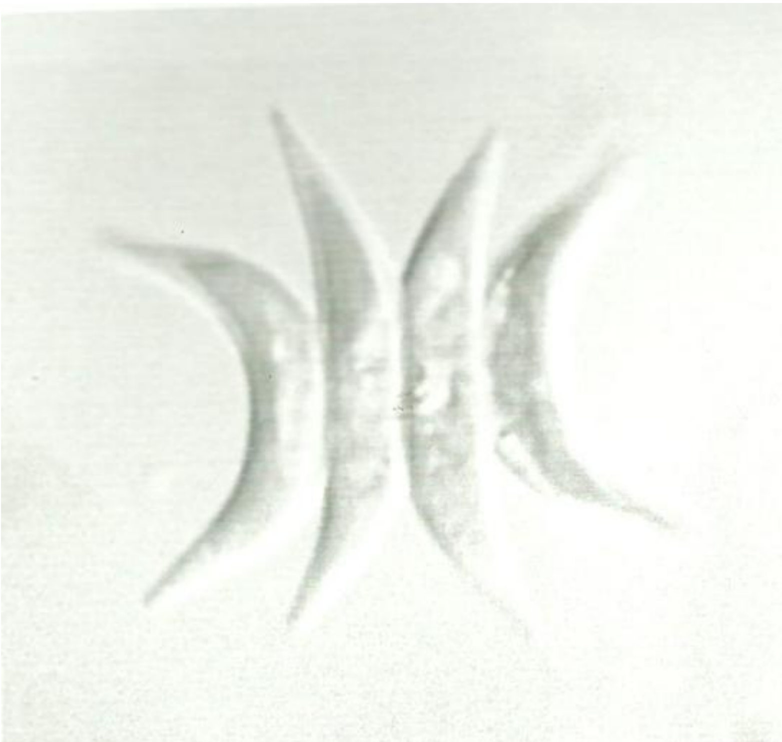

Figure 2: *Scenedesmusfacatuschodat*

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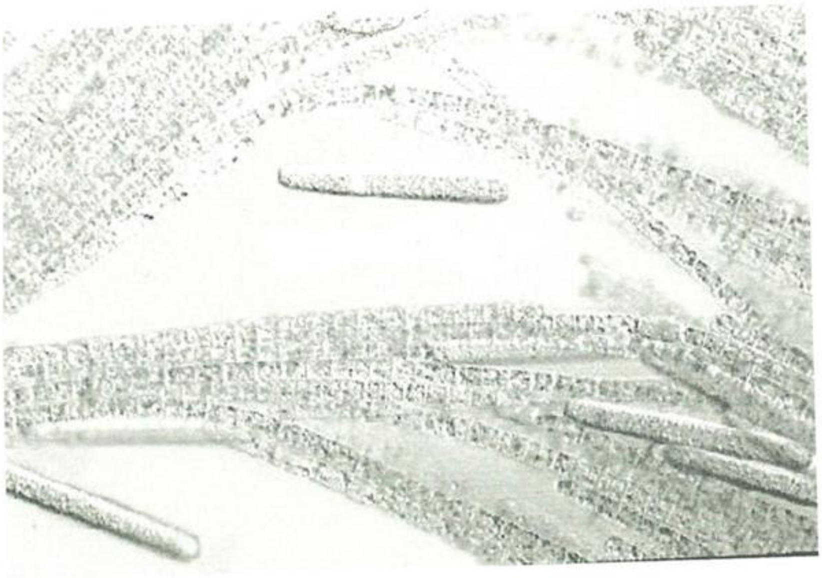

Figure 3: *Aphanizomenonflos-aquae*

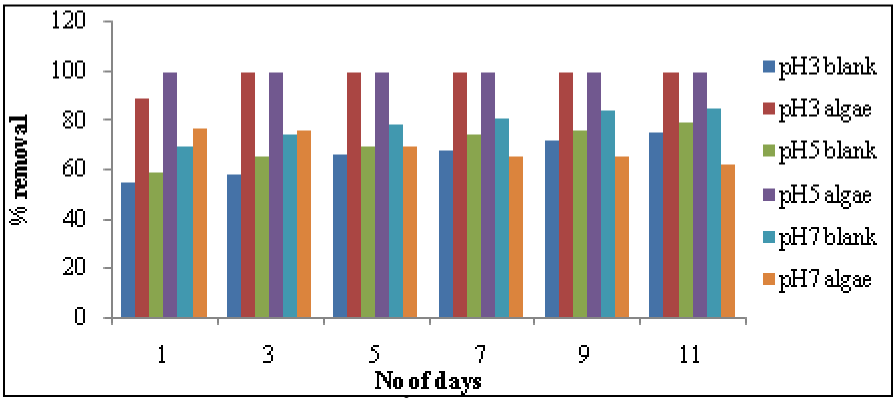

Figure 4: Percentage removal of Lead (Pb^{2+}) by *Synochromonaselaeochrus*with contact time

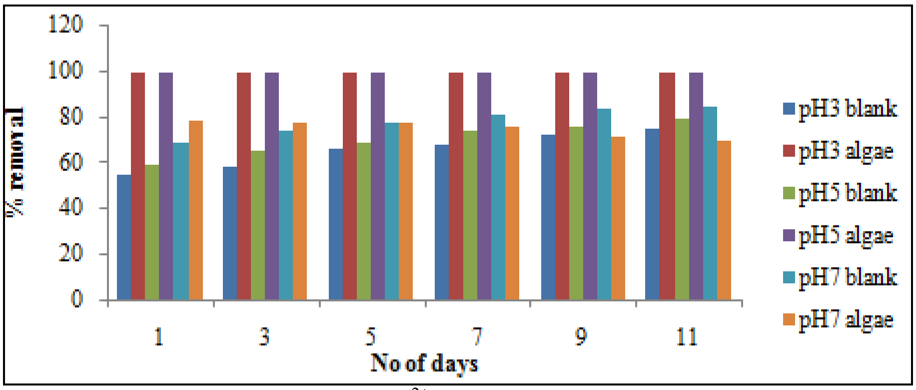

Figure 5: Percentage removal of Lead (Pb^{2+}) by *Scenedesmusfacatuschodat*with contact time

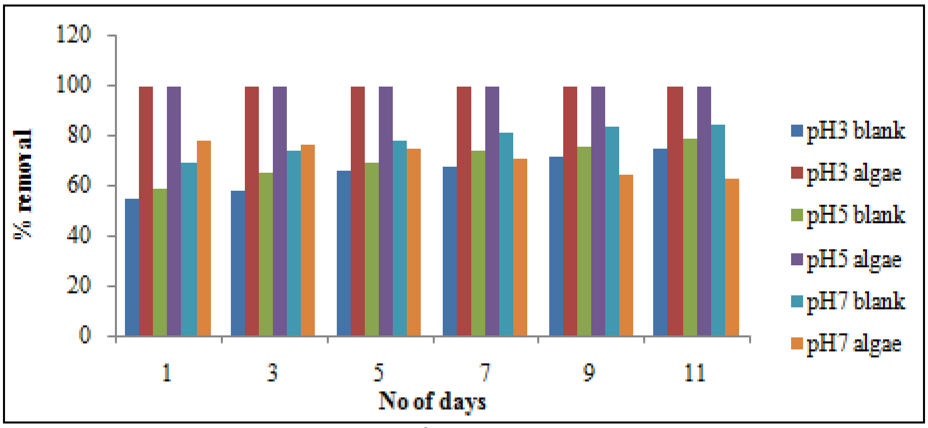

Figure 6: Percentage removal of Lead (Pb^{2+}) by *Aphanizomenonflos-aquae*with contact time

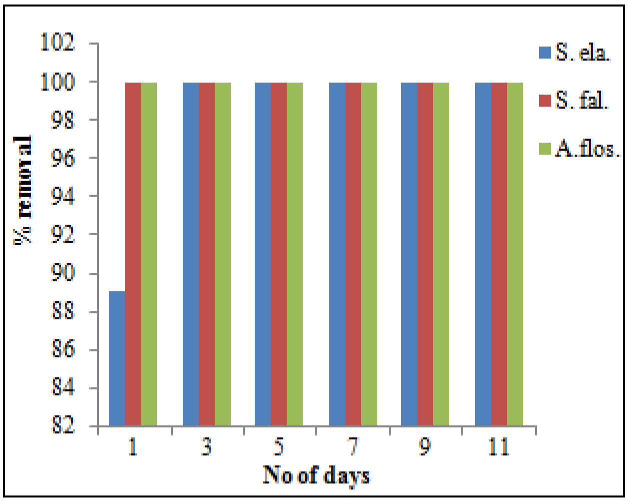

Figure 7: Percentage removal of Lead (Pb^{2+}) by *Synochromonaselaeochrus, Scenedesmusfacatuschodat*and *Aphanizomenonflos-aquae*at pH 3 with contact time

4. Discussion

The result of this investigation showed that *Synochromonaselaeochrus, Scenedesmusfacatuschodat*and *Aphanizomenonflos-aquae* (Fig. 1,2 and 3) are able to remove Lead (Pb^{2+}) from industrial effluent. This was possibly due to their ability to bind metals by chemical sorbents such as Carboxylic groups, Phosphoryl groups and Amino groups on their cell surface and to intracellular ligands. This correlates with the observation of previous work reported, that algae accumulate high concentrations of metals [11]. The varied metal sorption ability of these algae species could be attributed to the fact that algae have varied cell wall composition. This is in agreement with the report of [2]. From Fig. 4 to 6 presented, *Synochromonaselaeochrus* performed best at pH 5 while *Scenedesmusfacatuschodat* and *Aphanizomenonflos-aquae*performed best at pH 3 and 5. All the algae species performed least at pH 7.This is in accordance with the report of[2] that acidic pH (3-5) is most favorable for the sorption of metal ions by algae. At pH 3, *Scenedesmusfacatuschodat* and *Aphanizomenonflos-aquae* were able to remove Lead (Pb^{2+}) better (completely) than *Synochromonaselaeochrus*at day 1 (Fig. 7).This could be attributed to the fact that metal sorption ability of algae varies greatly from species to species as reported [2].

5. Conclusion

The results of this present study have shown that algae are able to sorption heavy metals from industrial wastewater. This ability is largely dependent on pH, length of time and type of algae species. Biosorption of Lead (Pb^{2+}) by the algae species means that these algae can be used by industries for heavy metal removal from their effluent before being discharged into the environment. This will reduce environmental pollution and improve economic value.

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