Potential Applications of Cyanobacteria in Industrial Effluents-A Review

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Abstract
Biodiversity and its application of cyanobacteria for the treatment of domestic and industrial effluents have received more attention during the recent years. Cyanobacteria have the capacity to utilize nitrogenous compounds, ammonia and phosphates; in addition, they accumulate metal ions such as Cr, Co, Cu and Zn very effectively. It has been observed that immobilized cyanobacteria have greater potential than its counterparts, i.e., free cells. Immobilization of cyanobacteria has been widely reported with considerable success. The present study focused attention on the review of papers potential application of cyanobacteria for the removal of heavy metal ions, nutrients, pesticide from the waste water of different effluents.

Keywords: Cyanobacteria; Effluent treatment; Immobilization; Removal of nutrients

Introduction
Utilization of cyanobacteria in effluent treatment is a recent phenomenon. The idea was proposed by [1] and initial experiments were performed by [2]. Since 1980, momentum of using cyanobacteria in waste water treatment has increased and since then several papers have appeared [3-5]. It has great potential to take up external nutrients such as ammonium, nitrate, orthophosphate and heavy metals [6]. Hence it could be a good candidate for tertiary treatment of urban, agricultural, industrial effluents, in turn, helps in solving eutrophication and metal toxicity problem in aquatic ecosystems.

Cyanobacteria, also known as blue green algae comprise a unique group of organisms with worldwide distribution. These are considered as algae because of their microscopic morphology, pigmentation and oxygen evolving photosynthesis. They are by far the largest group of photosynthetic prokaryotic as judged by their widespread occurrence, frequency, abundance and morphological diversity.

The recent past studies on cyanobacteria have emphasized their important role in ecosystems. They grow at any place and in any environment where moisture and sun light are available. However, specific algae grow in specific environment and therefore their distributional pattern, ecology, periodicity, qualitative and quantitative occurrences differ widely. The abundance and composition of blue green algal population in surface waters of ponds and lakes have been discussed by many workers. It is said that they flourish well either in nutrients rich warm water or at times in water with apparently low temperature and bright light conditions [7-10].

The major problem in utilization of microorganisms in any industrial or waste water treatment is harvesting of the biomass. This is solved by the strategy of immobilization. Even since its discovery it has been used in various application, depending on the suitability of immobilizing materials, biomass and cross linking material.

Immobilization technique is essential not only in waste water treatment but also in various industries [11]. This precludes the use of supporting material obtained either naturally including agar, alginate and carrageenan or synthetics such as polyacrylamide and polyurethane. Between these two natural polymers have an advantage over artificial polymers due to latter’s toxicity on biomass.

Cyanobacteria in Industrial Effluents
There are numerous reports dealing with the floristic and ecology of lentic and lotic algae. However, the algal flora of waste water system has not been investigated much [12-18]. In composition of fresh water system, algae in waste water are exposed to different environmental stress and a study the way for further waste treatment programmed using the indicator species. In the light of this, many investigators start working on the biodiversity of algae and particularly cyanobacteria in different industrial effluents. Such studies have been carried out with some industrial effluents such as oil refinery, fertilizer factory and brewery [19], distilleries [20], Dye, Paper mill, Sugar mill and Pharmaceutical [21]. In all the investigations, it has been reported that cyanobacteria dominated over other group of algae.

Among cyanobacteria, *Oscillatoria* is found to be the dominant genus followed by *Phormidium*, *Lyngbya* and some unicellular forms. Most effluent contains low oxygen, moderate level of nutrients and required pH for the flourished growth of cyanobacteria. Many scientists reported of the same as the reason for the abundance of cyanobacteria in industrial effluents. These findings show that there are certain species of cyanobacteria which are tolerant to pollution and resist environmental stress caused by the pollution. Such species can be used as ‘Marker species’ or indicators of particular habitat as pointed out by [22,23]. The indicator species otherwise represent the actual survivors of the habitat and their abundance indicate their adaptation to know habitat.

Role of Cyanobacteria in Wastewater Treatment
Cyanobacteria have long been recognized as having enormous potential for use in biotechnology, especially in agriculture, and now slowly drift is towards their use in wastewater treatment, because of the following reasons.

- Cyanobacterial growth does not require energy rich compounds like other non photo synthetic microorganisms.
- Cyanobacteria have simple growth requirements which use

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water as a source of reluctant. This character gives them as edge over other photosynthetic bacteria.

- Many cyanobacteria combine photosynthesis and nitrogen fixation. This is another advantage over other eukaryotic photosynthetic organisms.
- Cyanobacterial biomass production is in abundance and this can be used as food for animals [24] an important source for extraction of high value substances like vitamins and drug intermediates [25]. Nitrogen fixation [26] hydrogen production [24], light energy photo conversion and amino acid production.
- They are environmental friendly and do not cause toxicity to other biotic components.
- Separation of cyanobacterial biomass is much easier than other microbial biomass due to their size.

**Applications of Cyanobacteria**

A few cyanobacterial strains were used by various authors in waste water treatment and almost all of these under laboratory conditions [3,27-29]. A few studies do indicate cyanobacterial strains having potential in treating effluents from primary settled swine [30], Paper mill, sewage [31,32], Phenolic compounds [33], Dairy [34] Dye, [23] and Sago Industries [35]. However none of the cyanobacterial strains have been commercially exploited.

**Immobilized Cyanobacteria**

The application of cyanobacterial cultures for specific and use in effluent treatment has been reported. The use of free cells is rather rare in comparison to immobilized cells, since immobilization of cells offers various advantages and the process is cost effective. Several researchers have focused their attention on immobilized cyanobacteria for treating industrial effluents.

Several methods of immobilization of cyanobacteria have been reported in literature. Though, majority of the works pertain to entrapment of cells in natural polymers [3,11,36] or synthetic polymers [37,38] a few reports are available on cross linking with various compounds. The viability of the cells is affected by the cross-linking agents, though the structural stability is enhanced in comparison to entrapment in natural polymers.

During immobilization and after immobilization of biomass, the cross-linking material used for immobilization is found to the change the equation of waste water treatment [39]. Stability and mechanical properties of immobilizing system [40] several cross-linking materials are reported in the literature, they include: aldehydes, polysaccharides, sulphones, vinylketones and epoxy [11].

**Removal of Nutrients**

Many studies have demonstrated the success of using the algal cultures to remove nutrients from waste water rich in nitrogenous and phosphorous compounds [41-44] and hence they have been used extensively in stabilization ponds and in tertiary treatment of sewage for the removal of pollutants from the waste water.

Suspended cultivation of microalgae is one of the biological processes for the removal of nitrogenous compounds from waste waters. Several species of microalgae particularly cyanobacteria such as Oscillatoria [22,23,32,45-47] Phormidium [48-50] Aphanocapsa [34] and Westiellopsis [22] have been successfully used for the treatment of effluents from various industries. These studies concluded that cyanobacteria efficiently take-up nitrogenous compounds, Phosphorus from the effluents and thereby reducing the pollution load.

Though suspended cultivation of microalgae is one of the biological processes for the removal of nutrients from the waste waters, some difficulties limit the practical application of suspended microalgae which include (i) monospecificates and good operation conditions are hard to be maintained and (ii) microalgae are difficult to be separated from the effluent before discharge and hence, only few process such as stabilization pond [51] and high rate algal pond [16] have been developed. Recently, the use of immobilization to entrap microalgae for removal of nutrients from waste waters shows potential to solve the above problems [3,22,54]. Several matrices such as agarose [55], Carageen [56], chitosan [3], alginate [9,54] and polyurethane foam [9,37,22] have been used for the immobilization of microalgae process involving immobilized cells have been attempted in the treatment of effluents containing materials such as phenols [56], paper mill sludge [57], distillery waters [20], rubber press wastes [58], olive oil mill wastes [59], diary waste waters [52] and dye effluent including colour removal [22,23]. From the above studies it is concluded that immobilized microalgae are more efficient in removing various nutrients from waste water than suspended cultivation.

**Removal of Metal**

Increased use of metals and chemicals in various industries like mining, mineral processing and extra-metallurgical operations is alarming which results in the production of large quantities of aqueous effluents which contain high levels of metals. Such effluents pose environmental disposal problem. Removal of such toxic metals from effluents to the environmentally acceptable limits using cost-effective and environmental friendly manner assumes a great significance.

Cyanobacteria possesses high metal absorption capacity and very high multiplication rate. Such characters have encouraged the application of this microbial biomass in detoxification of effluents [60] and have an edge over conventional waste water treatment facilities [61]. Moreover, cyanobacteria being photosynthetic in nature provide a favorable condition for removal of heavy metals from the environment because their interior pH is almost two units higher than surrounding liquid [62], and hence it provides resistance to mass transfer of products out of the biofilm [63].

Generally, immobilized cyanobacteria have more potential in metal removal than their free living counterpart [64,57] Immobilized Anabaena dolion showed an increased uptake of Cu and Fe, i.e., in the order of 45 and 23 per cent higher than that of free living cells [29]. While [36] working with immobilized A. dolium showed that Cr and Ni removal by free living cells were 15 to 20 per cent and 10 to 30 percent less compared with that of immobilized cells.

The mechanism of metal removal by microbes is generally active process and occurs in two phases: (i) A rapid binding of caution to the negatively charged groups of cell walls and (ii) Followed by a subsequent metabolism dependent intracellular uptake [65-67]. Higher uptake of metals by immobilized cells over free living cells is ascribed to enhanced photosynthetic energy productivity of immobilized cells [68]. However, higher metal uptake due to increased cell wall permeability in immobilized cells is not ruled out [69].

Different metal uptake studies with marine algal biomass indicated that the absorption of heavy metals by biomass depends on the size of the particle and such uptake is within one order of magnitude. Lead
is found to be the best sorbed metal followed by others in decreasing order and it is established that keeping the metal ion concentration constant (200mg/l) the adsorption capacity of glutaraldehyde cross-linked Sargassum fluitans is pb > Cd > Cu > Ni > Zn [39]. However, the adsorption capacity of biomass changes with the change in metal ion concentration and it is found that at low concentration the removal efficiency is more [70].

**Removal of Pesticides**

The bioaccumulation and biomagnifications of residual insecticides in phytoplankton’s which constitute the primary producers in the food chain are biologically and toxicologically significant. It is well established that algal biomass have larger surface are attracting biophilic pesticide molecules thus helping in predicting the impact of pollution in aquatic system attention on the usage of algae, particularly Cyanobacteria for removal of toxicants from waste water treatment and as bioassay organisms for testing the toxicity of chemicals has been drawn in recent years. Depending on the type, biological property and concentration of pesticides and the algal strains, their effect could be inhibitory, selective or even stimulator. It has been observed that cyanobacterial forms used in biofertilizers are capable of tolerating pesticides levels recommended for fields applications. Insecticides are generally less toxic to BGA than their pesticides.

Cyanobacteria have been reported to accumulate very high concentration of insecticides. Synechococcus elongates, Anacystis nidulans and Microcystes aeruginosa have been able to degrade many organophosphorus and organochlornine insecticides from the aquatic system. Thus it seems that cyanobacteria can be mass cultured in waste water lagoon to degrade organic matter, removal of pollution load and to meet the requirement on nitrogenous fertilizers with minimal investment compared to the conventional waste water treatment plant.

The recent interest in algae and more specifically cyanobacterial biomass production using waste water has necessitated a thorough understanding of the influence of these waters on the physiology and biochemistry of these organisms. Now serious attempt has yet been made in this direction. Only a few have investigated [52,31,32,47,22] the effect of effluents on the physiology and biochemistry of the cyanobacterial systems. To develop suitable and efficient treatment system, it is obligatory to understand the mutual influence and interactions between the effluents and the organisms, so that manipulations to improve the treatment system become feasible and hence the future scenario must to select suitable strains of cyanobacteria which would be minimally influenced by the adverse conditions in the effluent, but would help removing pollutants maximally [71-75].

**Conclusion**

The application of cyanobacterial cultures for the treatment of industrial effluents has been well recognized. Hence, these studies though indicate the potential of cyanobacteria and are not reliable unless large-scale field trials are done. More research is desired to prepare reusable immobilized particles containing cyanobacteria. Efforts should be made to look for cheap systems and materials. The engineering studies using cyanobacteria are needed. It is essential to undertake large-scale engineering studies using free or immobilized cells for the treatment of effluents. Parallel studies on physiology and biochemical aspects of cyanobacterial culturing novel methods of immobilization including co-immobilization of various species are required to be done for symbiotic interaction among them which will result in synergetic enhancement of removal capabilities.

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**References**


