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Full Length Research Article

Waste Water Treatments Using Cyanobacteria

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Abstract

The purpose of the current research was to screen cyanobacteria from waste water treatments to find out the efficiency of heavy metal removal. Totally, 22 cyanobacteria were screened, such as *Arthrospira jenneri, Aphanocapsa koordersi, A. platensis, Gloeocapsa crepidium, G. gelatinosa, G. livida, G. punctata, G. samoensis, G. sanguine, Hyella caespitose, Oscillatoria acuminate, O. amoena, O. homogenea, O. laetevirens, O. minimus, O. pseudogeminata, O. schultzii, O. subbrevis, O. trichoides, Spirulina laxissima, S. meneghiniana* and *S. subtilissima for various waste waters such as dairy waste water, kitchen waste water, fish pond discharge and municipal waste water*. Screening of cyanobacteria treatment of wastewater reduces the BOD, COD, TN and TP. The removing maximum percentages are determined by the kitchen waste water and fish pond discharge, whereas biochemical oxygen demand, chemical oxygen demand, total nitrogen, and total phosphorus by the selected potential cyanobacteria like *Oscillatoria trichoides* (121.0%, 135.5%, 30.5%, and 10.9%) and *Spirulina laxissima* (105.7%, 115.4%, 32.7%, and 11.5%). The removal efficiency of heavy metals such as Cu^{2+}, Fe^{2+}, Zn^{2+} and Pb^{2+}. The maximum achieved removals were recorded at 99.88% and 99.84% for Zn^{2+} (*Oscillatoria trichoides*) in kitchen waste water and fish pond discharge. The significance of variance at a confidence level of $P<0.05$ and $P<0.01$ is recorded. The use of cyanobacteria performs a variety of tasks in the assembly of excess food, the treatment of wastewater, and the production of valuable biomass, all of which have a variety of uses. For a healthy environment and society, it is essential to remove heavy metal ions from wastewater.

Key words: Cyanobacteria, Chemical oxygen demand, Biochemical oxygen demand, Biomass, Waste water treatments, Heavy metals

Wastewater is produced in huge quantities each day in developing nations like India as a result of increasing population and growing industry. In India, a variety of conventional methods are employed for wastewater treatment, however they are very costly and not practical. The problems of traditional methods are being resolved by the introduction of various innovative environmentally friendly technical wastewater treatment methods nowadays [1]. Wastewater treatment systems exploiting photosynthetic microorganisms have lately arisen as an encouraging substitute to conservative biological processes [2]. However, over the last ten10 years, there has been a significant rise in research interest in the use of cyanobacteria to treat wastewater discharged from various locations, with encouraging results for both organic and inorganic discharge [3-4]. Additionally, cyanobacterial biofilms show significant prospects for use in the treatment of wastewater. The biofilm matrix defends the microbial inhabitants from the stresses of the environment [5]. Microalgae are especially helpful for reducing the contents of inorganic nitrogen and phosphorus in wastewater because they may use both of these wastewater pollutants for growth [6-7]. Wastewater-derived microalgae cultures can significantly contribute in the management of marine ecosystems by providing an inexpensive and environmentally friendly method for wastewater treatment. Wastewater. It is beneficial to use dairy effluent for micro algal cultures because it uses more freshwater, costs less to add nutrients, removes the remaining nitrogen and phosphorus, and produces micro algal biomass that may be used to make biofuel or even other high-value byproducts [8, 9, 10]. Every ecosystem on Earth includes heavy metals, which are naturally occurring in soil and crustal elements with a density greater than 5 g cm^3. For basic physiological and chemical processes in both plants and animals, heavy metals are essential. However, some heavy metals have the potential to poison living organisms. Arsenic (As), cadmium (Cd), copper (Cu), chromium (Cr), lead (Pb),

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manganese (Mn), Mercury (Hg), nickel (Ni), and zinc (Zn) are heavy metals that are usually present in wastewater [11]. Activities that discharge wastewater with significant levels of contaminants, such as heavy metals, must be removed before discharging the effluent to natural water sources [12-13]. Traditional physical techniques are also used to treat industrial wastewater, with adsorption being the most common due to its simplicity of operation [14]. Due to their long biological half-lives, the environmental effects of these wastewater's toxic heavy metal concentration releases have proved difficult to forecast [15].

Furthermore, this technique is not environmentally friendly because it produces a lot of toxic sludges that are difficult to dewater and manage [16]. In cellular absorption, the microalgae remove nutrients, and the biomass they produce can be used to recover resources [17]. The conventional biological nutrient removal method needs many reactors, which raises the operational complexity. Microalgae's strong capacity for nitrogen uptake has garnered interest in wastewater treatment in recent years [18-20]. When compared to physical and chemical systems, biological treatment systems have attracted global attention and assisted in the development of comparatively effective, affordable, and environmentally safe treatment technologies [21]. These features, which are frequently caused by the luxuriant growth of algae forms in eutrophic waters, can be manipulated to remove different kinds of inorganic and associated compounds through their metabolic processes [22]. Cyanobacteria are among the most promising microorganisms for absorbing heavy metals and carrying out oxygenic photosynthesis. Cyanobacteria provide a number of advantages that make them desirable hosts for biodegradative genes to increase their capacity for biodegradation [23]. Aquatic plant biomass, either micro or macro-organisms, can be used to accumulate metal ions from water in one of two ways. The first is known as biosorption, which is an energy-free process of binding metals to cell walls, while the second is known as bioaccumulation, which is an energy-intensive process of metal uptake into cells [24-25]. Compared to physical and chemical techniques, using living aquatic plants to absorb metals is more favourable. This reduces their availability and makes them less dangerous [24-27]. It was previously demonstrated that a packed bed column was the most practical method for heavy metal absorption because it had a high absorbent capacity and improved effluent quality [28]. The difficult task of growing microalgae and the high cost of the growth medium seriously limit the algal industry. One of the recent trends is to look for new photosynthetic organisms in various environments that have rapid growth rates, high biomass yields, and high potential for use. These organisms could then be mass cultured in wastewater, reducing the need for commercial medium while the wastewater is always cleaned [29]. Wastewater discharge is increasing together with the water shortage as a result of increased urban, agricultural, and industrial pollution. Eutrophication of water bodies is brought on by the discharge of nutrients from wastewater into the environment. Additionally, a number of governmental organisations have now embraced the circular economy concept in an attempt to reduce and control the pollution which wastewater produces [30]. The generated sludge would mainly be made up of microalgae after the wastewater had completed micro algal bioremediation [31-32]. A further objective of the present study was to screen was to screen for four different waste water treatments and the efficiency of heavy metal removal from cyanobacteria.

MATERIALS AND METHODS

The collection of dairy waste water, kitchen waste water, fish pond discharge and municipal wastewater. The basic parameters of waste water samples were all investigated. The removal efficiency of heavy metals like Cu^{2+}, Fe^{2+}, Zn^{2+} and Pb^{2+} are selected potential cyanobacteria were analysed. From research sample, 22 cyanobacteria were isolated and this work was screened by the 22 cyanobacteria from four different wastewaters. Then the efficiency of heavy metal removal from selected potential cyanobacteria.

Cultivation of cyanobacteria

A conical flask with a non-absorbent cotton plug was loaded with around 20 ml of the collected algae, which was then immersed in four media solutions that were previously prepared. These flasks were placed in an incubator, and for 10 to 30 days, the growth of cyanobacteria in all four media was observed. The incubator was set to a 25°C temperature with such a 2000–2500 lux light intensity. Cyanobacteria cultures received 16 and 8 hours, respectively, of alternate exposure to light and dark. The pH of the solution was kept at 7-8. The BG-11 medium was discovered to be the best of the four for the growth of cyanobacteria. Wastewater was treated using algae and a media solution [33-36].

Screening of cyanobacteria and treatment of wastewater

Cyanobacteria used to treat wastewater in a batch system. Filtered algae from the media solution were mixed with about 1000 ml of wastewater in a 2 lit beaker. Using an air pump, pumped through the solution. For approximately 10 to 12 days, the temperature, colour, and pH of the solution were continuously recorded. The treated solutions BOD, COD, TN and TP were estimated after twelve days [37]. In accordance with the standards provided by the American Public Health Association [38], the BOD, COD, TN, and TP were measured.

Cyanobacterial growth rate determination

An ultraviolet spectrophotometer (UV-1800, Shimadzu) was used to measure the optical density (OD) of each sample of cyanobacteria culture in order to detect chlorophyll [39]. The following formulas were employed to calculate each strain's corresponding first-order growth rate (k_1, day^{-1}):

$$OD_{strain} = OD_i - OD_{control}$$

$$Ln\ (OD^t_{strain}) = k_1 t + Ln\ (OD^t_{strain})$$

The optical density of the inoculated ADE sample is represented by OD_i, and the optical density of the control ADE sample is denoted by $OD_{control}$ (positive control). Using Excel, related linear regression statistics were calculated.

Heavy metal determination

The two living species of the tested cyanobacteria namely *Oscillatoria trichoides* and *Spirulina laxissima* were selected for removal efficiency of heavy metals. Using an atomic absorption spectrophotometer (AAS) and the standard procedure described in the "Standard Methods for Examination of Water and Wastewater" [40], treated samples and raw water were both characterised for the selected dissolved heavy metals after treatment. Membrane filters were used to separate water samples, and each sample was then individually analysed with a specific lamp and wavelength. The proposed system's heavy metal removal efficiencies were calculated.

Statistical analysis

The results of the experiments were carried out in triplicate and are expressed as mean values with a standard deviation by using Microsoft Excel 2007. The differences between the mean values were calculated using Tukey's test at the 0.05 and 0.01 level and using the Origin Software.

RESULTS AND DISCUSSION

Screening of cyanobacteria from wastewater and treatments

A total of four cyanobacteria strains were involved in the primary screening method, and their time series growth curves were examined [37]. In the present study, a total of 22 cyanobacteria were screened, such as *Arthrospira jenneri, Aphanocapsa koordersi, A. platensis, Gloeocapsa crepidium, G. gelatinosa, G. livida, G. punctata, G. samoensis, G. sanguine, Hyella caespitose, Oscillatoria acuminate, O. amoena, O. homogenea, O. laetevirens, O. minimus, O. pseudogeminata, O. schultzii, O. subbrevis, O. trichoides, Spirulina laxissima, S. meneghiniana* and *S. subtilissima* for various waste waters, such as dairy waste water, kitchen waste water, fish pond discharge and municipal waste water (Fig 1-8).

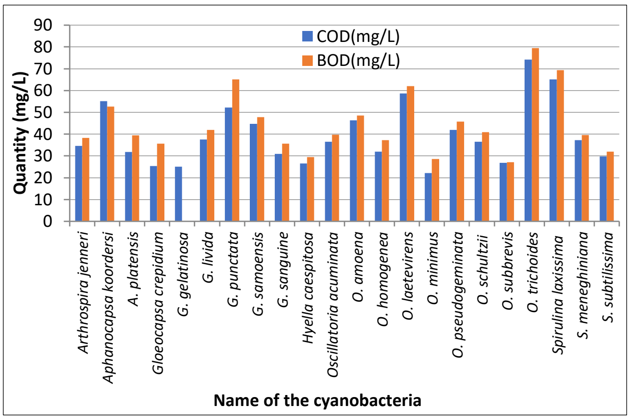

Fig 1 Screening of COD and BOD from cyanobacteria strains in dairy waste water

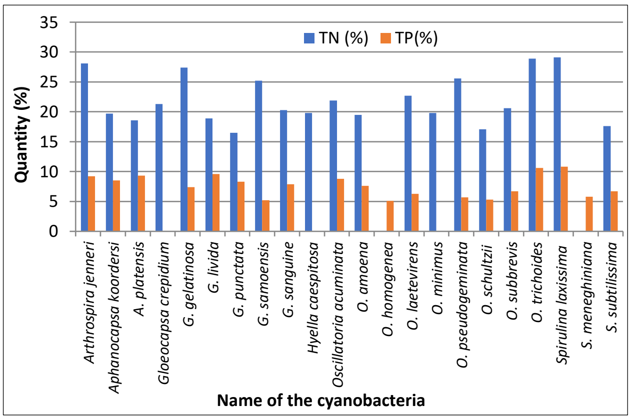

Fig 2 Screening of TN and TP from cyanobacteria strains in dairy waste water

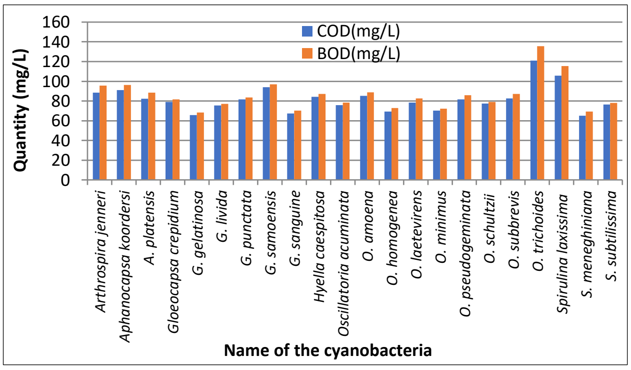

Fig 3 Screening of COD and BOD from cyanobacteria strains in Kitchen waste water

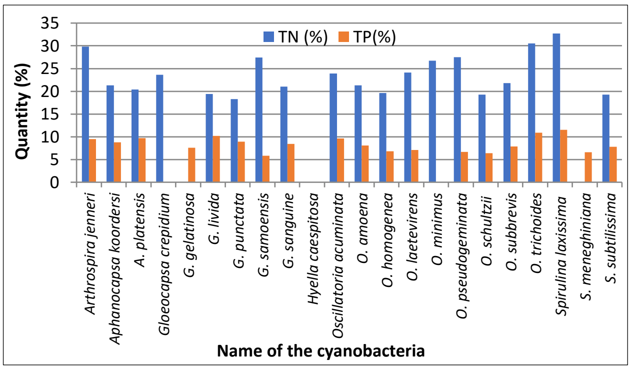

Fig 4 Screening of TN and TP from cyanobacteria strains in Kitchen waste water

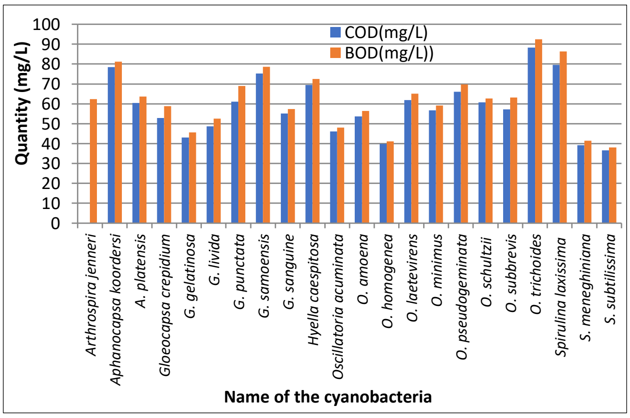

Fig 5 Screening of COD and BOD from cyanobacteria strains in fish pond discharge

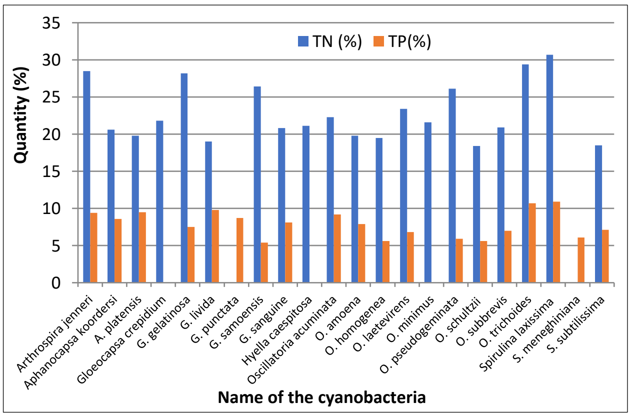

Fig 6 Screening of TN and TP from cyanobacteria strains in fish pond discharge

Dairy wastewater

According to the species, different microalgae have varied growth rates. Different biomass productivity of microalgae in dairy wastewater has been reported by various researchers [11]. Large amounts of seriously polluted wastewater were produced by the dairy wastewater. When the algal cells were cultivated in dairy wastewater, cyanobacterial Chlorella usually achieved a high level of nutrient pollutant removal and was effectively used [41-42]. Cyanobacteria are a very appealing option for low-cost and sustainable wastewater treatment due to their ability to grow well in nutrient-rich environments, consume nutrients effectively, and accumulate metals from the wastewater [43]. Cyanobacteria were used to treat dairy wastewater and produce biomass while reducing the nutritional content of the wastewater [7]. On a bench outdoor scale, it was possible to cultivate *Chlorella zofingiensis* in dairy wastewater and obtain a maximum TP and TN removal of 97.5% and 51.7%, respectively [44]. In an uncertain and changing indoor lab-scale experiment using dairy wastewater [45] obtained 0.86 g/L biomass, 89.92-91.97% TP, and 84.18-89.70% COD removal. In this study, the removal efficiency of dairy wastewater, COD and BOD (mg/L) were presented at highest concentration in the cyanobacteria were *Oscillatoria trichoides* (74.2 mg/L and 79.5 mg/L) and *Spirulina laxissima* (65.1 mg/L and 69.3 mg/L). Typical nitrogen (TN) and phosphorus (TP) highest concentration in the *O. trichoides* were (28.9% and 10.6%) and *S. laxissima* (29.1% and 10.8%) respectively. The maximum concentration in the COD and BOD (mg/L) were *Aphanocapsa koordersi* 55.2mg/L and *O. laetevirens* 58.6mg/L in COD and *G. punctata* 65.1mg/L and *O. laetevirens* 62.1mg/L in BOD, *Arthrospira jenneri* 28.1% and *G. gelatinosa* 27.4 in TN and *Arthrospira jenneri* 9.2%, *Aphanocapsa koordersi* 9.3% and *G.livida* 9.6% in TP. The minimum concentration in the COD and BOD (mg/L) from dairy wastewater were presented at the cyanobacteria was *Gloeocapsa gelatinosa* 25.1mg/L, *G. crepidium* 25.4mg/L, *Hyella caespitose* 26.5mg/L and *O. subbrevis* 26.9mg/L in COD and *Hyella caespitose* 29.5mg/L, *O. minimus* 28.6mg/L and *O. subbrevis* 27.1mg/L in BOD. The minimum TN and TP were presented at *Aphanocapsa platensis* 18.6%, *G. livida* 18.9%, *G. punctata* 16.5%, *O. Schultzii* 17.1% and *S. subtilissima* 17.6% in TN and *G. samoensis* 5.2%, *Oscillatoria homogenea* 5.1%, *O. pseudogeminata* 5.7%, *O. schultzii* 5.3% and *S. meneghiniana* 5.8% in TP. The cyanobacteria of not applicable (N/A) are *G. gelatinosa* from BOD (mg/L), *O. homogenea* and *S. meneghiniana* from TN (%) and *G. crepidium, Hyella caespitosa* and *O. minimus* from TP (%) are recorded. The four removal efficiency COD (mg/L), BOD (mg/L), TN (%) and TP (%) were maximum and minimum are mostly recorded with the cyanobacteria is *Aphanocapsa koordersi, Arthrospira jenneri, O. schultzii, G. livida* and *O. subbrevis* respectively (Fig 1-2).

Kitchen wastewater

Additionally, 68.4% BOD and 67.2% Chemical oxygen demand (COD) were removed from household wastewater using biological treatment with algae [46]. In 48 hours of interaction with *C. vulgaris* at 30°C, [47] reported a 78% COD reduction. The algal-bacterial system [48] used for wastewater treatment was able to remove approximately 70–80% of the COD. By using filamentous green algae in an artificial wetland and a high-rate algal pond [49] reported a relatively low efficiency for COD removal in the range of 59.2% to 69.4%. The domestic wastewater, the average specific growth rates in the exponential period were 0.412, 0.429, 0.343, and 0.948. It also revealed that the removal rates for phosphorus, and COD were 74–82%, 83–90%, and 50–83.0%, respectively [50]. In this study, the efficiency of kitchen wastewater removal, the cyanobacteria with the highest COD and BOD (mg/L) concentrations were *O. trichoides* (121.0mg/L and 135.5mg/L) and *S. laxissina* (105.7mg/L and 115.4mg/L). The greatest typical concentrations of nitrogen (TN) and phosphorus (TP) were *O. trichoides* (30.5% and 10.9%) and *S. laxissina* (32.7% and 11.5%) respectively. The maximum concentration of *G. samoensis* 94.1mg/L and *Aphanocapsa koordersi* 91.1mg/L in COD, *Arthrospira jenneri* 95.7mg/L, *Aphanocapsa koordersi* 96.2 mg/L and *G. samoensis* 96.8 mg/L in BOD, *Arthrospira jenneri* 29.8% and *O. pseudogeminata* 27.5% in TN and *G. livida* 10.2%, *Arthrospira jenneri* 9.5%, *Aphanocapsa platensis* 9.7%, and *O. acuminata* 9.6% in TP. The minimum presented at the cyanobacteria were *G. gelatinosa* 65.7mg/L, *G. sanguine* 67.2mg/L, *O. homogenea* 69.2mg/L and *S. meneghiniana* 65.2mg/L in COD, *G. gelatinosa* 68.2mg/L and *S. meneghiniana* 69.4mg/L, *G. livida* 19.4%, *O. homogenea* 19.6%, *O. schultzii* 19.3% and *S. subtlissima* 19.3% in TN and the *G. samoensis* 5.8%, *O. homogenea* 6.8%, *O. pseudogeminata* 6.7%, *O. schultzii* 6.4% and *S. meneghiniana* 6.6% in TP. The cyanobacteria of not applicable (N/A) are *G. gelatinosa* and *Hyella caespitose* from TN (%) and *G. crepidium*, *Hyella caespitose* and *O. minimus* from TP (%) are recorded. The four removal efficiency COD (mg/L), BOD (mg/L), TN (%) and TP (%) were maximum and minimum are mostly recorded with the cyanobacteria is *S. meneghiniana*, *Arthrospira jenneri*, *Aphanocapsa koordersi* and *O. homogenea* respectively (Fig 3-4).

Fish pond discharge

The effluent for the intensive aquaculture system usually has a high concentration of dissolved nitrogen compounds, generally in the form of ammonia, which are produced by the undigested feed and the wastes [51]. Cyanobacterial absorption of these nitrogenous compounds could be a sustainable alternative to bacterial nitrification of these compounds to gaseous nitrogen, as the produced biomass could be used as superior feed ingredients [52-54]. In microalgal-bacterial floc was used in a sequencing batch reactor to treat aquaculture wastewater successfully [55]; the simple separation of microalgal-bacterial floc by gravity sedimentation could reduce the total cost of aquaculture wastewater treatment. In China, investigate the removal of nutrients by the combined use of high-rate algal ponds and macrophyte systems. COD removals as a percentage were 54.5% in "winter" (8 days) and 44.5% in "summer" (4 days). Only around 50% of COD was removed on an annual average. However, the amount of dissolved COD that was removed as a percentage of the influent's overall COD was almost 73%. Although the effluent from the had a low dissolved COD concentration (about 60 mg/l), the total COD could be significant because of the algal biomass. The average removal rates for COD and phosphorus were around 50%, 75% and 90%. In particular, this system was effective at removing ammonia from wastewater [56]. In this study, the removal efficiency of fish pond discharge, COD and BOD (mg/L) were presented at highest concentration in the cyanobacteria were *Oscillatoria trichoides* (88.3 mg/L and 92.5 mg/L) and *Spirulina laxissima* (79.5 mg/L and 86.4 mg/L). Typical nitrogen (TN) and phosphorus (TP) highest concentration in the *O. trichoides* were (29.4% and 10.7%) and *S. laxissima* (30.7% and 10.9%) respectively. The maximum concentration in the COD and BOD (mg/L) were *Aphanocapsa koordersi* 78.5mg/L and *G. samoensis* 75.3mg/L in COD, *Aphanocapsa koordersi* 81.2mg/L, *G. samoensis* 78.6mg/L and *Hyella caespitose* 72.5mg/L in BOD, *Arthrospira jenneri* 28.5% and *G.gelatinosa* 28.2% in TN and *Arthrospira jenneri* 9.4%, *Aphanocapsa platensis* 9.5%, *G. livida* 9.8% and *O. acuminata* 9.2% in TP. The minimum concentration were noted at the cyanobacteria of *G. gelatinosa* 43.0mg/L, *G. livida* 48.7mg/L, *O. acuminata* 46.1mg/L, *O. homogenea* 39.8mg/L and *S. subtilissima* 36.7mg/L in COD, *G. gelatinosa* 45.7mg/L, *Oscillatoria acuminata* 48.1mg/L, *Oscillatoria homogenea* 41.1mg/L, *S. meneghiniana* 41.5mg/L and *S. subtilissima* 38.1mg/L in BOD, *O. schultzii* 18.4% and *S. subtilissima* 18.5% in TN and *G. samoensis* 5.4%, *O. homogenea* 5.6%, *O. schultzii* 5.6% and *O. pseudogeminata* 5.9% in TP respectively. The cyanobacteria of not applicable (N/A) are recorded with the *G. punctata* and *S. meneghiniana* from TN and *G. crepidium*, *Hyella caespitose* and *O. minimus* from TP. The four removal efficiency COD (mg/L), BOD (mg/L), TN (%) and TP (%) were maximum and minimum are mostly recorded with the cyanobacteria is *G.*

samoenis, Arhtrospira jenneri, Oscillatoria homogenea and S. subtlissima respectively (Fig 5-6).

Municipal wastewater

Municipal sewage wastewater (MSWW) usually has nitrogen and phosphorus values of 21.9–28.8 and 8.2-10.4 mg/L, respectively [57]. For the bacteria to completely consume the nitrogen and phosphorus in the MSWW, the concentration of dissolved organics is typically low [58]. Consequently, an advanced treatment procedure is used to remove too many nutrients after the activated sludge process (ASP) (N, P). The residual nitrogen and phosphorus from the ASP effluent could be removed by microalgae [50-60]. However, the MSWW may effectively remove nitrogen, phosphorus, BOD, and heavy metals through the production of microalgae [61-48]. Pathogens from the MSWW may also be removed by microalgae [41]. A local municipal wastewater treatment plant's treatment process flow was sampled at four different places, and carried out a study to assess the development of green algae Chlorella sp. and how effectively the algal growth removed metal ions, nitrogen, and phosphorus from the wastewaters [50]. The primary issue with most wastewaters is the high nutrient concentrations, particularly the TN and TP concentrations, which must be removed during wastewater treatment using expensive chemical-based treatments. In municipal wastewater, agricultural effluent, and farm wastewater, the TN and TP concentrations range from 10 to 60 mg/L, more than 1,000 mg/L, and 500 to 600 mg/L, respectively [62]. In this study, the removal efficiency of fish pond discharge, COD and BOD (mg/L) were presented at highest concentration in the cyanobacteria were *Oscillatoria trichoides* (77.2 mg/L and 86.0 mg/L) and *Spirulina laxissima* (71.0 mg/L and 82.6 mg/L). Typical nitrogen (TN) and phosphorus (TP) highest concentration in the *O. trichoides* were (26.7% and 9.6%) and *S. laxissima* (25.9% and 9.9%) respectively. The maximum concentration of cyanobacteria were *G.punctata* 60.4mg/L, *Hyella caespitose* 53.4mg/L and *G. crepidium* 52.7mg/L in COD, *G. punctata* 65.1mg/L and *G. sanguine* 67.1mg/L in BOD, *Arthrospira jenneri* 28.6%, *Aphanocapsa koordersi* 21.1%, *G. crepidium* 20.6%, *G. gelatinosa* 21.4% and *O. pseudogeminata* 20.8% in TN and *Arthrospira jenneri* 8.7% and *Aphanocapsa platensis* 8.1% in TP were noted. The minimum concentration of cyanobacteria were recorded with *Aphanocapsa koordersi* 21.0mg/L, *G. gelatinosa* 20.8mg/L, *O. amoena* 21.8mg/L, *O. pseudogeminata* 19.8mg/L and *S. subtilissima* 23.8mg/L in COD, *Aphanocapsa koordersi* 26.7mg/L, *G. gelatinosa* 27.4mg/L, *O. amoena* 24.3mg/L, *O. laetevirens* 23.7mg/L, *O. pseudogeminata* 21.6mg/L and *S. subtilissima* 26.4mg/L in BOD, *G. punctata* 15.0%, *O. laetevirens* 12.7%, *O. schultzii* 15.5% and *S. subtilissima* 13.7% in TN and *G. samoensis* 4.9%, *O. homogenea* 4.7%, *O. pseudogeminata* 4.5% and *O. schultzii* 4.9% in TP. The cyanobacteria of not applicable (N/A) are recorded with the *A. platensis* and *O. schultzii* from COD, *G. livida* from BOD, *S. meneghiniana* from TN and *G. gelatinosa*, *Hyella caespitose* and *O. minimus* from TP were noted. The four removal efficiency COD (mg/L), BOD (mg/L), TN (%) and TP (%) were maximum and minimum are mostly recorded with the cyanobacteria is *Aphanocapsa koordersi, S. subtilissima* and *O. schultzii* respectively (Fig 7-8).

In the current study, the dairy wastewater, kitchen wastewater, fish pond discharge and municipal wastewater in all parameters COD (mg/L), BOD (mg/L), TN (%) and TP (%) the cyanobacteria were *Arthrospira jenneri* and *Aphanocapsa koordersi* are maximum and minimum screened were *O. pseudogeminata*, *O. schultzii* and *O. homogenea*. The mostly screened by the cyanobacteria were *Oscillatoria trichoides* and *Spirulina laxissima* in all parameters. So, the next study is efficiency of removal heavy metals are the tested for selected cyanobacteria (Fig 1-8).

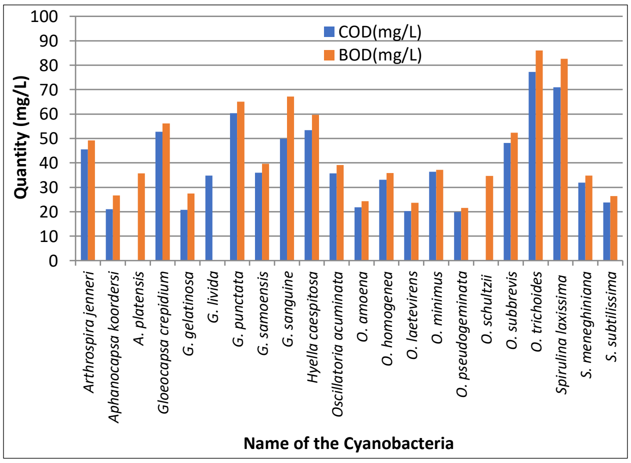

Fig 7 Screening of COD and BOD from cyanobacteria strains in Municipal waste water

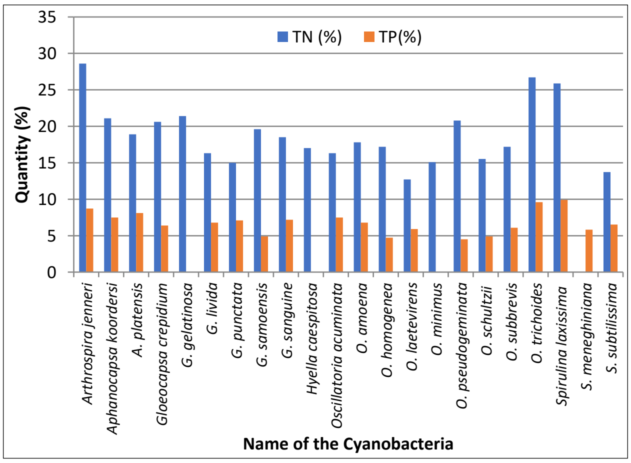

Fig 8 Screening of TN and TP from cyanobacteria strains in Municipal waste water

Removal efficiency of heavy metals

Four heavy metals, copper, iron, zinc, and lead, were found to be present in this effluent at high amounts. Because of this, the immobile cultures of *Anabaena variabilis* and *Tolypthrix ceytonica* were chosen to evaluate their ability to remove Cu^{2+}, Fe^{3+}, Zn^{2+}, and Pb^{2+} ions from the contaminated industrial wastewater [63]. The appearance of four heavy metals, namely copper, iron, zinc, and lead, was found after an analysis of the four different types of waste water used in this work, including dairy wastewater, kitchen wastewater, fish pond discharge, and municipal wastewater. As a result, *Oscillatoria trichoides* and *Spirulina laxissima* were chosen to test whether they were able to remove the Cu^{2+}, Fe^{3+}, Zn^{2+} and Pb^{2+} ions from the four different wastewaters. RE% is a function of the type of heavy metal, exposure time, and microbial species, according to the results of the residual concentrations and removal efficiencies of the four metals and four different waste water by the individual or mixed free cultures of potential cyanobacteria *Oscillatoria trichoides* and *Spirulina laxissima* (Table 1-4). Regardless of metal type, microbial species, or metal concentration, RE% of all the investigated metals are proportionally increased with exposure time. As a result, the experiment's highest removal % was observed (5h).

Efficiency of heavy metals removal in dairy wastewater

Anabaena variabilis and *Tolypthrix ceytonica*, two species of highly resistant cyanobacteria, were used to effectively treat the raw effluent of the Varta Company, which was contaminated with copper, iron, zinc, and lead. They showed a very rapid (6 h) increase in RE(s) % for all the contaminating metals, which can be slowed down by using serial units successively. *T. ceytonica* and the mixed culture removed 88.00%, 79.09%, 92.35%, and 37.11% of the copper, iron, zinc, and lead from the wastewater, respectively, whereas the free *Anabaena variabilis* culture removed 89.33%, 93.44%, 98.23%, and 86.67%. The results indicated that RE(s) % varies on the kind of heavy metal, the length of incubation, and the type of microbial species [64]. This was confirmed by, who observed that the competition between metal ions for binding sites on algal surfaces varied depending on the species of algae and the metal ions. The quantity and concentration of heavy metals, the type of biosorbent used, the physiological state of the cells, and the chemical makeup of the wastewater all influence the effectiveness of metal biosorption [65]. In this study, the residual concentration levels are reported at 0.16, 12.74, 6.21 and 4.52 mg/L for Cu^{2+}, $Fe^{3+,}$ Zn^{2+} and Pb^{2+} respectively. The highest RE% ranges achieved by the tested *O. trichoides*, *S. laxissima* and mixed *O. trichoides* and *S. laxissima* after five exposure hours were (85.09%, 75.09% and 74.19%) in copper, (88.19%, 86.35% and 82.49%) in iron, (99.62%, 94.32% and 95.41%) in zinc and (82.52%, 76.12% and 34.86%) in lead. The lowest RE% ranges in tested cultures were (21.52%, 52.30% and 33.25%) in copper, (65.56%, 71.28% and 65.47%) in iron, (82.33%, 78.25% and 84.26%) in zinc, (6.59%, 5.27% and 6.23%) in lead. The significance of variance at confidence level of cyanobacteria cultures presented were (0.003, 0.013 and 0.023) in copper, (0.001, 0.002 and 0.002) in iron, (0.001, 0.001 and 0.028) in zinc and (0.001, 0.003 and 0.002) in lead are noted. The maximum ranges are analysed by the heavy metal is zinc and very lowest ranges are presented at lead metal. The results indicated that free individual and mixed cultures of the two selected species were able to remove the tested metals at a very high rate and with very high RE% in the following order is $Zn^{2+} > Fe^{3+} > Cu^{2+} > Pb^{2+}$. The tested cultures also showed high selectivity (Table 1).

Table 1 Using separate and combined free-living cultures of at various exposure times, measurements of certain heavy metals in dairy waste water

Heavy metal	Time (h)	*Oscillatoria trichoides*		*Spirulina laxissima*		*Oscillatoria trichoides* and *Spirulina laxissima*		p
		RC	RE%	RC	RE%	RC	RE%	
Cu	0	0.162±0.002	-	-	-	-	-	-
	1	0.125±0.006	21.52^{l}	0.084±0.001	52.30^{l}	0.088±0.003	33.25^{l}	0.023
	2	0.105±0.008	27.31	0.061±0.003	63.07	0.055±0.001	66.74	0.013
	3	0.044±0.001	75.06	0.052±0.005	67.48	0.052±0.003	69.15	>0.05
	4	0.036±0.003	77.11	0.042±0.001	71.44	0.047±0.008	71.05	>0.05
	5	0.017±0.004	85.09^{h}	0.036±0.002	75.09^{h}	0.013±0.006	74.19^{h}	>0.05
r, p		0.91, 0.003*	-	0.77, 0.013*	-	0.69, 0.023*	-	-
Fe	0	12.74±0.542	-	-	-	-	-	-
	1	4.231±0.112	65.56^{l}	4.192±0.122	71.28^{l}	4.655±0.152	65.47^{l}	>0.05
	2	4.220±0.105	65.91	4.025±0.134	75.23	4.405±0.143	68.23	>0.05
	3	3.564±0.137	73.26	3.265±0.108	76.10	4.223±0.141	72.19	>0.05
	4	3.025±0.107	78.15	2.843±0.086	78.06	4.008±0.132	78.14	>0.05
	5	2.184±0.068	88.19^{h}	1.653±0.051	86.35^{h}	3.114±0.103	82.49^{h}	0.016
r, p		0.86, 0.001*	-	0.89, 0.002*	-	0.72, 0.002*	-	-
Zn	0	6.215±0.021	-	-	-	-	-	-
	1	0.520±0.011	82.33^{l}	1.055±0.012	78.25^{l}	0.685±0.021	84.26^{l}	>0.05
	2	0.261±0.007	88.52	0.744±0.035	85.12	0.610±0.005	88.74	>0.05
	3	0.227±0.004	96.21	0.557±0.018	88.23	0.445±0.008	91.52	>0.05
	4	0.116±0.002	97.28	0.487±0.016	91.18	0.421±0.003	92.57	>0.05
	5	0.091±0.007	99.62^{h}	0.361±0.011	94.32^{h}	0.320±0.016	95.41^{h}	>0.05
r, p		0.93, 0.001*	-	0.85, 0.001*	-	0.63, 0.028*	-	-
Pb	0	4.523±0.004	-	-	-	-	-	-
	1	4.571±0.003	6.59	4.224±0.152	5.27	4.450±0.153	6.23	0.041
	2	4.380±0.005	21.42	3.274±0.108	29.21	4.328±0.147	4.56	0.023
	3	3.513±0.008	57.10	2.744±0.096	41.74	4.105±0.132	8.75	0.001
	4	2.062±0.062	66.09	2.220±0.036	52.08	4.045±0.125	10.47	0.001
	5	1.563±0.050	82.52	1.056±0.012	76.12	2.847±0.110	34.86	0.012
r, p		0.83, 0.001*	-	0.74, 0.003*	-	0.62, 0.002*	-	-

^{l} The lowest recorded RE%

^{h} The highest recorded RE%

* Level of Significant variance at 0.05 and 0.01 (2-tailed)

Efficiency of heavy metals removal in kitchen wastewater

The ranges of RE(s)% obtained for Cu2+ by *A. variabilis* and *T. ceytonica*, and the mixed culture of *A. variabilis* and *T. ceytonica* are 20.67-89.33, 51.33-85.33, and 34.67-88.00, respectively. These ranges showed *A. variabilis* superior ability to remove Cu2+ compared to the other two cultures, followed by the mixed culture and *T. ceytonica*. The three cultures respective Fe3+ RE(s) % ranges were 68.59–93.44, 70.02–97.22, and 66.89–79.09, with *T. ceytonica* achieving the highest ranges, followed by *A. variabilis*, and then the mixed culture. The three cultures showed RE(s) % for Zn^{2+} of 86.47–98.23, 79.21–93.33, and 85.88–92.35, respectively, with *A. variabilis* removing more Zn^{2+} than the other two cultures, followed by the mixed culture, especially at exposures up to 5 h, then *T. Ceytonica* [63]. In this study, Cu^{2+}, Fe^{3+}, Zn^{2+} and Pb^{2+}, respectively, the residual concentration levels are reported to be 0.16, 12.74, 6.21, and 4.52 mg/L. The tested *O. trichoides, S. laxissima* and mixed *O. trichoides* and *S. laxissima* had the highest RE% ranges in copper (92.17%, 80.19%, and 85.05%), iron (90.28%, 91.52% and 86.13%), zinc (99.88%, 97.13% and 98.08%), and lead (87.44%, 78.06% and 39.48%) after five exposure hours. The tested cultures lowest RE% ranges were mostly for copper (42.13%, 59.28% and 48.11%), iron (67.23%, 75.15% and 68.09%), zinc (85.21%, 86.32% and 86.51%), and lead (8.19%, 8.56% and 8.44%). There were (0.004, 0.014 and 0.034) in copper, (0.001, 0.003and 0.001) in iron, (0.003, 0.002 and 0.004) in zinc, and (0.002, 0.002 and 0.001) for lead in the cyanobacteria cultures that were significant levels are presented. Zinc has the maximum ranges when analysed as a heavy metal, and lead metal has the lowest very highest ranges. The results showed that free individual and mixed cultures of the two selected species were able to remove the tested metals in the following order: $Zn^{2+} > Cu^{2+} > Fe^{3+} > Pb^{2+}$ at a very high rate and with very high RE%. The tested cultures showed a high level of selectivity (Table 2).

Table 2 Using separate and combined free-living cultures at various exposure times, measurements of certain heavy metals in kitchen waste water

Heavy metal	Time (h)	*Oscillatoria trichoides*		*Spirulina laxissima*		*Oscillatoria trichoides* and *Spirulina laxissima*		*p*
		RC	RE%	RC	RE%	RC	RE%	
Cu	0	0.196±0.003	-	-	-	-	-	-
	1	0.142±0.004	42.13	0.141±0.002	59.28	0.159±0.002	48.11	0.012
	2	0.129±0.005	45.08	0.120±0.001	64.10	0.137±0.003	68.74	>0.05
	3	0.074±0.002	88.16	0.096±0.005	69.08	0.115±0.001	74.28	>0.05
	4	0.045±0.001	89.05	0.088±0.002	74.66	0.093±0.004	77.23	0.024
	5	0.021±0.003	92.17	0.053±0.001	80.19	0.044±0.002	85.05	>0.05
r, p		0.96, 0.004	-	0.79, 0.014	-	0.71, 0.034	-	-
Fe	0	13.67±0.416	-	-	-	-	-	-
	1	4.458±0.124	67.23	4.316±0.158	75.15	4.812±0.168	68.09	>0.05
	2	4.423±0.108	68.52	4.302±0.145	79.00	4.745±0.127	70.28	>0.05
	3	4.216±0.091	74.11	3.864±0.123	83.15	4.675±0.103	75.62	0.011
	4	4.116±0.074	81.04	3.571±0.101	87.64	4.319±0.081	80.07	>0.05
	5	4.005±0.052	90.28	3.170±0.053	91.52	4.211±0.052	86.13	0.012
r, p		0.92, 0.001	-	0.90, 0.003	-	0.77, 0.001	-	-
Zn	0	6.758±0.062	-	-	-	-	-	-
	1	0.729±0.032	85.21	1.418±0.016	86.32	0.845±0.023	86.51	>0.05
	2	0.674±0.015	89.12	1.257±0.074	88.16	0.816±0.014	89.01	>0.05
	3	0.530±0.009	97.05	1.108±0.019	89.29	0.770±0.010	93.64	>0.05
	4	0.456±0.006	99.46	1.089±0.024	92.46	0.618±0.008	96.33	0.015
	5	0.320±0.002	99.88	1.032±0.010	97.13	0.553±0002	98.08	0.026
r, p		0.97, 0.003	-	0.89, 0.002	-	0.71, 0.004	-	-
Pb	0	4.805±0.002	-	-	-	-	-	-
	1	4.612±0.001	8.19	4.513±0.127	8.56	4.716±0.129	8.44	0.023
	2	4.571±0.002	25.09	4.356±0.115	34.18	4.673±0.106	5.21	0.016
	3	3.720±0.003	59.06	4.328±0.102	46.29	4.611±0.052	8.82	0.003
	4	2.642±0.001	78.11	4.119±0.084	54.71	4.570±0.036	11.12	0.001
	5	1.925±0.003	87.44	3.817±0.017	78.06	4.336±0.012	39.48	0.001
r, p		0.85, 0.002	-	0.76, 0.002	-	0.66, 0.001	-	-

[l] The lowest recorded RE%
[h] The highest recorded RE%
* Level of Significant variance at 0.05 and 0.01 (2-tailed)

Efficiency of heavy metals removal in fish pond discharge

Treatment methods for heavy metal pollution in wastewater includes chemical, physical, and biological processes. Biosorption, bio removal, bio-separation, and sometimes phytoremediation are terms used to describe a promising method that employs living aquatic plants to sorb metals from water as an alternative to physiological and chemical methods [66]. When it comes to waste water, the electroplating, electronics, and metal cleaning sectors commonly heavy metals and causes significant issues with water pollution. It has been demonstrated that microalgae are very efficient at removing as a result of their large surface area and strong binding affinity, heavy metals from wastewater. In addition, microalgae have a negative surface charge and a strong affinity for heavy metal ions, they are especially useful for the analysis of effective at purifying wastewater [67]. In this study, the residual concentration levels are reported at 0.17, 13.08, 6.51 and 4.58 mg/L for Cu^{2+}, Fe^{3+}, Zn^{2+} and Pb^{2+} respectively. The highest RE% ranges achieved by the tested *O. trichoides*, *S. laxissima* and mixed *O. trichoides* and *S. laxissima* after five exposure hours were (88.09%, 76.20% and 80.52%) in copper, (90.18%, 88.13% and 83.45%) in iron, (99.84%, 96.22% and 96.05%) in zinc and (85.62%, 77.19% and 36.17%) in lead. The lowest RE% ranges in tested cultures were (30.02%, 55.27% and 37.41%) in copper, (67.02%, 72.35% and 67.18%) in iron, (84.26%, 80.25% and 84.87%) in zinc, (7.25%, 7.54% and 7.41%) in lead. The significance of variance at confidence level of cyanobacteria cultures presented were (0.003, 0.001and 0.003) in copper, (0.001, 0.003 and 0.004) in iron, (0.002, 0.001 and 0.002) in zinc and (0.003, 0.002 and 0.001) in lead are recorded. The maximum ranges are analysed by the heavy metal is zinc and very lowest ranges are presented at iron metal. The results indicated that free individual and mixed cultures of the two selected species were able to remove the tested metals at a very high rate and with very high RE% in the following order is $Zn^{2+} > Fe^{3+} > Cu^{2+} > Pb^{2+}$. The tested cultures also showed high selectivity (Table 3).

Table 3 Using separate and combined free-living cultures at various exposure times, measurements of certain heavy metals in fish pond discharge

Heavy metal	Time (h)	*Oscillatoria trichoides*		*Spirulina laxissima*		*Oscillatoria trichoides* and *Spirulina laxissima*		*p*
		RC	RE%	RC	RE%	RC	RE%	
Cu	0	0.174±0.001	-	-	-	-	-	-
	1	0.133±0.002	30.02	0.125±0.003	55.27	0.124±0.005	37.41	0.015
	2	0.129±0.001	35.28	0.113±0.001	63.58	0.110±0.001	66.85	>0.05
	3	0.117±0.003	77.14	0.086±0.004	68.17	0.085±0.002	70.15	>0.05
	4	0.096±0.002	80.18	0.075±0.001	73.39	0.066±0.003	75.22	0.005
	5	0.068±0.001	8	0.066±0.003	76.20	0.042±0.001	80.52	0.013
			8.09					
r, p		0.92, 0.003	-	0.78, 0.001	-	0.70,0.003	-	-
Fe	0	13.08±4.69	-	-	-	-	-	-
	1	4.338±0.120	67.02	4.251±0.005	72.35	4.715±0.152	67.18	>0.05
	2	4.328±0.112	67.85	4.156±0.003	77.18	4.683±0.140	69.08	>0.05
	3	4.316±0.087	74.26	4.128±0.005	81.09	4.669±0.126	73.11	0.013
	4	4.285±0.065	79.07	4.113±0.007	85.61	4.612±0.108	78.66	0.017
	5	4.215±0.047	90.18	4.095±0.001	88.13	4.502±0.085	83.45	0.026
r, p		0.88, 0.001	-	0.90,0.003	-	0.75,0.004	-	-
Zn	0	6.512±0.033	-	-	-	-	-	-
	1	0.590±0.026	84.26	1.259±0.027	80.25	0.735±0.038	84.87	>0.05
	2	0.442±0.017	89.51	1.247±0.019	86.48	0.645±0.025	88.79	>0.05
	3	0.413±0.009	96.58	1.236±0.011	88.74	0.623±0.014	91.76	>0.05
	4	0.356±0.005	97.89	1.205±0.009	91.82	0.527±0.008	94.13	0.025
	5	0.225±0.001	99.84	1.196±0.004	96.22	0.475±0.002	96.05	0.011
r, p		0.94, 0.002	-	0.87, 0.001	-	0.65, 0.002	-	-
Pb	0	4.584±0.002	-	-	-	-	-	-
	1	4.425±0.001	7.25	4.328±0.132	7.54	4.628±0.143	7.41	0.014
	2	4.381±0.005	26.18	4.310±0.116	31.25	4.607±0.125	4.68	0.016
	3	4.319±0.001	57.64	4.251±0.108	44.27	4.526±0.103	8.80	0.005
	4	4.271±0.004	75.18	4.186±0.047	53.28	4.476±0.086	10.85	0.001
	5	3.841±0.003	85.62	4.058±0.018	77.19	4.265±0.016	36.17	0.002
r, p		0.88, 0.003	-	0.75, 0.002	-	0.65, 0.001	-	-

[l] The lowest recorded RE%
[h] The highest recorded RE%
* Level of Significant variance at 0.05 and 0.01 (2-tailed)

Efficiency of heavy metals removal in municipal wastewater

Because different cyanobacterial species in mixed cultures fight with one another for resources, individual cultures are almost as effective at removing heavy metals as mixed cultures are. However, it is crucial to use the right immobilisation approach when applying microbial biomass to sorb metal ions during a continuous industrial process. Immobilized biomass has a number of benefits, including higher biomass loading, less clogging in continuous flow systems, and increased reusability [68-69]. For the goal of algal tertiary wastewater treatment, immobilisation appears to be one of the finest methods for physically separating micro-algal cells from their growing medium. Additionally, nitrogen removal from wastewater using immobilisation on screens was higher than with traditional biological tertiary wastewater treatments [70-72,73]. In this study, Cu^{2+}, Fe^{3+}, Zn^{2+}, and Pb^{2+}, respectively, the residual concentration levels are reported to be 0.15, 11.59, 6.01 and 4.02 mg/L. The tested *O. trichoides, S. laxissima* and mixed *O. trichoides* and *S. laxissima* had the highest RE% ranges in copper (82.01%, 71.45%, and 72.48%), iron (86.32%, 82.17%, and 80.56%), zinc (97.23%, 91.44%, and 92.56%), and lead (97.23%, 91.44%, and 92.56%) after five exposure hours. The tested cultures lowest RE% ranges were mostly for copper (20.18%, 50.26% and 30.11), iron (63.10%, 65.18% and 64.29%), zinc (80.23%, 76.29%, and 81.06%), and lead (5.14%, 4.25%, and 5.16%). There were (0.004, 0.012, and 0.016) in copper, (0.002, 0.001and 0.001) in iron, (0.002, 0.004 and 0.025) in zinc, and (0.002, 0.002 and 0.003) for lead in the cyanobacteria cultures that were significant levels are presented. Zinc has the maximum ranges when analysed as a heavy metal, and lead metal has the lowest very highest ranges. The results showed that free individual and mixed cultures of the two selected species were able to remove the tested metals in the following order: $Zn^{2+} > Fe^{3+} > Cu^{2+} > Pb^{2+}$ at a very high rate and with very high RE%. The tested cultures showed a high level of selectivity (Table 4).

Also demonstrated that the immobilised *T. ceytonica* was more effective in removing lead from wastewater than *A. variabilis*, and that the bio removal of lead by the mixed culture was higher than in the individual cultures. It was noted that using sewage effluent that contained heavy metals such Fe^{3+}, Zn^{2+}, Cu^{2+} and Pb^{2+}encouraged the growth of algae and cyanobacteria as early as 1982 [74]. Because of their easily accessible low cost, relatively large surface area, and strong binding affinity, algae have been discovered to be potential appropriate biosorbents [75,76]. In this current study, the cyanobacteria *O. trichoides* and *S. laxissima* and mixed *O. trichoides* and *S. laxissima* from kitchen wastewater and fish pond discharge are maximum presented in removal efficiency (RE%) of heavy metals and in the same order for $Zn^{2+} > Fe^{3+} > Cu^{2+} > Pb^{2+}$ when compared with dairy wastewater and municipal wastewater. In four different wastewaters the highest removal efficiency for zinc heavy metal in cyanobacteria *O. trichoides* and *S. laxissima* and mixed *O. trichoides* and *S. laxissima*. The level of significance variance at 0.05 and 0.01 (2-tailed) are calculated and significant for all heavy metals zinc, copper, iron and lead in four different wastewaters, respectively (Table 1-4).

Table 4 Using separate and combined free-living cultures at various exposure times, measurements of certain heavy metals in municipal waste water

Heavy metal	Time (h)	*Oscillatoria trichoides*		*Spirulina laxissima*		*Oscillatoria trichoides* and *Spirulina laxissima*		*p*
		RC	RE%	RC	RE%	RC	RE%	
Cu	0	0.158±0.003	-	-	-	-	-	-
	1	0.101±0.001	20.18	0.079±0.002	50.26	0.074±0.002	30.11	0.015
	2	0.098±0.006	22.56	0.066±0.003	61.74	0.062±0.006	63.51	0.018
	3	0.040±0.005	74.28	0.053±0.004	65.28	0.058±0.002	65.47	>0.05
	4	0.021±0.008	75.11	0.029±0.003	69.18	0.041±0.005	69.23	>0.05
	5	0.009±0.001	82.01	0.011±0.001	71.45	0.021±0.005	72.48	>0.05
r, p		0.87, 0.004	-	0.84, 0.012	-	0.65, 0.016	-	-
Fe	0	11.59±0.427	-	-	-	-	-	-
	1	4.115±0.106	63.10	4.058±0.115	65.18	4.118±0.164	64.29	>0.05
	2	4.108±0.096	63.59	4.021±0.105	73.59	4.012±0.152	65.18	>0.05
	3	4.086±0.074	70.55	3.517±0.074	74.11	3.816±0.122	70.52	>0.05
	4	3.841±0.015	75.29	2.116±0.041	77.08	3.618±0.108	75.19	>0.05
	5	3.547±0.017	86.32	1.528±0.016	82.17	3.418±0.074	80.56	>0.05
r, p		0.85, 0.002	-	0.86, 0.001	-	0.70, 0.001	-	-
Zn	0	6.012±0.054	-	-	-	-	-	-
	1	0.408±0.015	80.23	0.984±0.016	76.29	0.574±0.023	81.06	>0.05
	2	0.378±0.014	84.79	0.819±0.024	83.11	0.489±0.015	85.18	0.014
	3	0.321±0.009	92.16	0.715±0.019	87.19	0.411±0.026	89.14	0.009
	4	0.306±0.005	95.11	0.529±0.025	89.46	0.376±0.015	90.74	>0.05
	5	0.285±0.001	97.23	0.331±0.014	91.44	0.310±0.018	92.56	>0.05
r, p		0.90, 0.002	-	0.83, 0.004	-	0.61, 0.025	-	-
Pb	0	4.028±0.002	-	-	-	-	-	-
	1	4.117±0.009	5.14	3.857±0.129	4.25	4.117±0.124	5.16	0.016
	2	4.103±0.008	20.58	3.518±0.116	22.87	4.057±0.110	3.95	0.024
	3	3.814±0.006	55.13	3.214±0.086	36.54	3.829±0.086	7.48	0.003
	4	3.410±0.006	62.07	3.159±0.024	50.66	3.538±0.019	9.74	0.012
	5	3.226±0.001	80.15	3.085±0.013	71.48	3.110±0.026	30.12	0.005
r, p		0.80, 0.002	-	0.71, 0.002	-	0.60, 0.003	-	-

[l] The lowest recorded RE%
[h] The highest recorded RE%
* Level of Significant variance at 0.05 and 0.01 (2-tailed)

CONCLUSION

In this study, to screen for four different waste water treatments and the efficiency of heavy metal removal from cyanobacteria. It is informed that before discharging the treated wastewater in the stream, it is necessary to remove cyanobacteria from the treated effluent to conform with general standards for wastewater discharge. This is based on the various studies conducted to treat the wastewater using microalgae show that the cyanobacteria reactor has a significant reduction in nutrients, BOD and COD and other toxic chemicals but increase in total solids due to the growth of cyanobacteria. The efficiency of the cyanobacteria-based wastewater treatment system in removing nutrients is very high. The method is 5-32% effective at removing nitrogen and phosphorus. Additionally, the treatment method is successful in removing 15-135% of COD, BOD and other pollutants from wastewater. The reduction of various wastewater parameters (BOD, COD, TN and TP) by microalgae indicates that the use of microalgae for industrial wastewater treatment may be an alternative to more involved chemical treatments. After treatment, the cyanobacteria biomass can be utilised to produce biofuels, fertilizer, hydrogen gas, and pharmaceuticals. This method allows for the environmentally and economically favourable treatment of large volumes of wastewater. It is clear that the selected cyanobacterial species, either free-living or fixed, singular or in mixtures, have excellent bio removal capacities toward metal contaminants found in water or wastewater, even at extremely high concentrations, with some exhibiting selection preferences over others. This benefit could be effectively employed to decontaminate both natural aquatic ecosystems and wastewater effluents. Additionally, it offers a cost-effective and excellent instrument for the recovery and reuse of treated, suitable wastewater for any purpose, such as irrigation of agricultural non-edible crops. It also provides protection for the received environments. The application of cyanobacteria executes a variety of tasks in the assembly of surplus food, the treatment of wastewater, and the production of useful biomass, all of which have a wide range of applications. In addition to this, as they are photosynthetic autotrophs, they enrich and improve the quality of the water. As a result, wastewater treatment for cyanobacteria cultures may be useful and as an advanced environmental, friendly treatment method. This combined biotechnology plan for wastewater treatment and nutrient recovery will be improved by additional experiments.

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