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Integrated Wastewater Reuse Management for Sustainable Agriculture Development: A Green Technology Approach.

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Abstract: It is recognised that water is a key resource for life and development. The UN recommends a minimum of 50 litres of water per person per day to drink, wash and cook. Water scarcity and climate change form a dual challenge to food and environmental security. There are number of industries consuming large volume of water for the production of various products. Simultaneously, it releases equal volume of wastewater into the environment. It creates lots of additional problems to human beings as well as to sustainable environment. More dangerously, the ground water is also contaminated and thereby reduces the accessibility of potable drinking water to the consumers. Recycling of wastewater by using a novel green technology an "environmentally sound technology" is more suitable option. In this context, a new nano-biocarbon technology is developed by using biomaterials and is effectively used for treatment of highly contaminated wastewater. In the present study, a CETP grey wastewater is used for the treatment. The results indicate that, the nano-biocarbon technology works well and all the parameters are significantly reduced. The main pollution parameter such as COD and BOD is reduced to 86.98 and 81.17%, respectively. Alkalinity of the wastewater is reduced to 70.32% by making the water suitable for crop irrigation. After the treatment process, the concentration of heavy metals such as Cr (81.75%), Pb (85.79%) and Ni (90.40%) are significantly reduced. *Setaria glauca* was grown by using the treated wastewater and total biomass weight of 2.5 kg per pot was produced.

Key words: Wastewater treatment · Water reuse · Fodder crops · Nano-biocarbon · Green technology

INTRODUCTION

Water pollution is one of the most important environmental problems in the world. In developing countries, fast-growing urban populations are demanding more fresh water and food, while generating greater volumes of domestic wastewater. Sustaining water availability for agriculture in the near future presents a great challenge and opportunity for the communities in the developing countries. They must play a fundamental role in creating and maintaining access to and availability of this scarce resource for present and future generations. This would effectively improve agricultural productivity and overall economic growth. Adequate water supplies to meet basic human needs are essential to maintain and enhance the welfare of all the inhabitants [1].

It is a realization that, wastewater is becoming an increasingly important source of water for irrigation and aquaculture practices [2, 3]. The demands of growing urban communities for both food and water require the agricultural sector not only to increase food production but also to reduce its use of natural water resources. At the same time the volume of sewage effluent is increasing and safe disposal can be difficult. Due to the lack of comprehensive wastewater management, a major portion of the wastewater pollutes natural water bodies. Many communities in most developing countries don't have reliable access to supplies of clean water. As the demand for water increases, making more efficient use of water becomes very important. Water re-use should be seriously considered before water availability and demand [4].

Municipal treatment facilities are designed to treat raw wastewater to produce a liquid effluent of suitable quality that can be disposed to the natural surface waters with minimum impact on human health or the environment.

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In both developed and developing countries, the most prevalent practice is the application of municipal wastewater to land. In modernized countries where environmental standards are applied, much of the wastewater is treated prior to use for irrigation of fodder, fiber and seed crops and, to a limited extent, for the irrigation of orchards, vineyards and other crops. Other important uses of wastewater include, recharge of groundwater, landscaping, industry, construction, dust control, wildlife habitat improvement and aquaculture [5].

Problem Statement/Issue: Wastewater may contain toxic chemicals which are harmful to the growth and development of plants. It may also contain bacteria and other micro-organisms which are harmful to agricultural workers, consumers and when eaten by animals, may in turn infect the people who eat the contaminated meat. Among wastewater-related infections, diarrhoeal diseases are the top cause of death among children in the developing world [6]. In this context, the health risks in relation to the level of contamination and the re-used wastewater control measures should be adopted along with the new risk-reducing guidelines on wastewater irrigation from the World Health Organization (WHO) [7] should be followed scientifically.

Re-use requires careful planning and monitoring, adequate and suitable treatment, appropriate legislation and implementation and quality standards [8]. This research paper presents the application of nano-biocarbon based green technology for the treatment of industrial wastewater and reuse management for sustainable agriculture.

Literature Review: Textile dyes are the essential cause of color in the discharged wastewaters [9]. Removal of color and heavy metals from wastewater is a sustainable alternative to reduce its ill-effects. As an example, the heavy metals such as lead, chromium, nickel are classified as prevalent toxic metal and major environmental health problem can enter the food chain through drinking water and crop products [10].

Cr(VI) is a known carcinogen and designated as hazardous pollutant. Cr(III), on the other hand, is less toxic than Cr(VI) and is listed as an essential element. However, it is poisonous at high concentration. The maximum allowable limit of total chromium in drinking water as recommended by the World Health Organization is 0.05 mg/L [11].

Generally, nickel exists as Ni(II) in aqueous solution and it causes cancer of lungs, nose and bone at high concentration of Ni(II). It is reported that Ni(II) concentration in wastewaters varies from a low value of 0.5 mg/L to a high value of 1000 mg/L while the maximum permissible concentration of Ni(II) in aqueous media is only 0.02 mg/L [12].

Number of technologies has been investigated for the effective removal of toxic metals from contaminated water, such as precipitation, membrane filtration, reverse osmosis, solvent extraction and electrolysis, biological treatment, ion-exchange processes and adsorption. Among them, adsorption technique has advantage of high efficiency, adsorbate-specificity, cost effectiveness as well as eco-friendly materials as adsorbents [13 – 15]. The risks of generating secondary pollutants, associated with many of the metal removal methods are of great concern.

Activated carbons derived from different sources (plants, animal residues, agricultural waste products and others) were produced and used as adsorbent material [16]. Activated carbons were characterized by a large specific surface area, which is an important physical property. Due to its characteristics, activated carbons are effective adsorbent for the removal of many pollutant compounds (organic, inorganic and biological) of environmental concern [17, 18].

In this context, intensive research and development efforts are being made all over the world to develop low cost adsorbents for remediation of toxic metal ions and organic contaminants from wastewater [19]. Biosorption is an attractive green technology for treatment of wastewater for removing potential toxic heavy metals and organic compounds from industrial wastewater. In this study an attempt was made to use, the leaves of Marigold (*Tagetes spp. – Asteraceae*) for the preparation of nano-biocarbon for the potential removal of color and toxic heavy metals from an industrial wastewater. The treated industrial wastewater is applied in pilot scale for cultivation of *Setaria glauca* a fodder grass for livestock applications.

MATERIALS AND METHODS

All the chemicals required in the present study were of analytical grade and purchased from Merck (KGaA Darmstadt, Germany).

Preparation of Biocarbon: The biocarbon (BC) was prepared by treating the Marigold (*Tagetes spp. – Asteraceae*) leaf powder with the concentrated sulphuric acid (Sp. gr.1.84) in a weight ratio of 1:1.8 (biomaterial: acid). The resulting black product was kept in an air-free oven, maintained at 160 ± 5 °C for 6 h followed by washing with distilled water until free of excess acid and then dried at 120 ± 5 °C [20]. This material was finely crushed and the particle size between 90 and 125 µm was used. Marigold plant is selected for the adsorption experiments are mainly due to its eco-friendly nature and its rich carbon content.

Physico-Chemical Analysis of Wastewater: Wastewater was collected from a combined effluent treatment plant (CETP) in an industrial area in north district of Tamil Nadu, India. The wastewater was grey color. The important physico-chemical parameters such as pH, alkalinity, suspended solids (SS), total dissolved solids (TDS), electrical conductivity (EC), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD) and heavy metals mainly for Cr, Pb and Ni were performed by using standard methods [21]. The amount of metal ions content in wastewater was analyzed using Shimadzu AAS 6200 instrument with air–acetylene flame system.

Treatment of Industrial Wastewater: It involves a preliminary treatment with screening for the removal any dirt materials. After this, a dirt free grey water samples were collected in clean polythene containers and subjected to continuous batch biosorption process with pre-defined equilibrium data. The biosorption process was carried out at laboratory temperature of 28 ± 2°C. For the evaluation of treatment capacity of biocarbon, 100mL of grey water sample was used with 2.5g/100mL of biocarbon dose. The effective contact time was estimated at 120 min with 250 rpm. The pH of the test solution was monitored by using a Hanna pH Instruments (Italy). The experiments were carried out in triplicates and the average values obtained and used for further applications. The analytical data were analyzed and standard deviations of the statistical tests were carried out using programme of analysis of variance (ANOVA) by using SPSS 12 package.

Growth of *Setaria glauca* (*Poaceae*): It is also called as Cattail millet. The growth of fodder grass was monitored in pots (15cm diameter) experiments. The quality seed are spiked in soil and water is allowed to wet the soil. Mainly, length of shoot and leaves of grass was observed at the end of 120 days. This is the observed agricultural period for complete maturation of the fodder grass. The soil quality (mainly essential nutritional aspects) was also taken care during the growth of *Setaria glauca*.

RESULTS AND DISCUSSION

Characteristics of Biocarbon: The biocarbon was characterized for its quality control parameters which are essential to understand the adsorptive behaviour of the biocarbon. The details of characteristics of the biocarbon are already reported [11]. It is observed that, the surface and particle size is relatively high and is responsible for potential removal of metal ions and organic molecules from wastewater system. The results indicated that the biocarbon has good adsorption capacity.

Re-use of Treated Wastewater: The analytical results of important physico-chemical parameters for the raw wastewater has been evaluated and presented in the Fig. 1. It indicates that, the wastewater is highly contaminated with organic pollutants and heavy metals. Because of higher amount of dissolved solids and organic load, the electrical conductivity is significantly increased in the wastewater. Certain extent, the higher organic load is also contributing the rise in biological oxygen demand (BOD) of the wastewater. This will also obviously raise the microbial population of the wastewater. Since, the wastewater is flowing; the suspended solids are not in alarming level. Fig. 2 represents the characteristics of treated wastewater, the results indicate that, the nano-biocarbon technology works well and all the parameters are significantly reduced. The main pollution parameter such as COD and BOD is reduced to 86.98 and 81.17% respectively. Alkalinity of the wastewater is reduced to 70.32% by making the water suitable for crop irrigation. Relatively, the level of TDS is good in wastewater. The level of heavy metals such as Cr, Pb and Ni is high in the raw and treated wastewater was presented in the Fig. 3. It will definitely cause toxic effects in humans and animals by using this wastewater for any irrigation purpose. Hence, proper treatment is mandatory for this type of wastewater for reuse purpose for land and irrigation purpose. After the treatment process, the concentration of heavy metals such as Cr (81.75%), Pb (85.79%) and Ni (90.40%) are well reduced and are within the agricultural quality of wastewater. Similarly, it is well observed that, treated wastewater has been used successfully for crop irrigation and urban forming worldwide [22, 23].

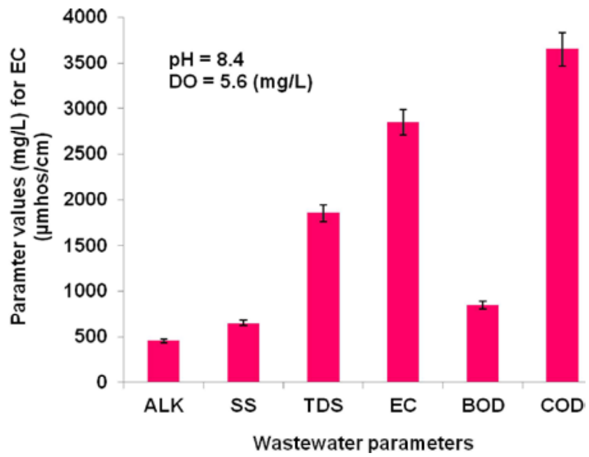

Fig. 1: Characteristics of raw wastewater.

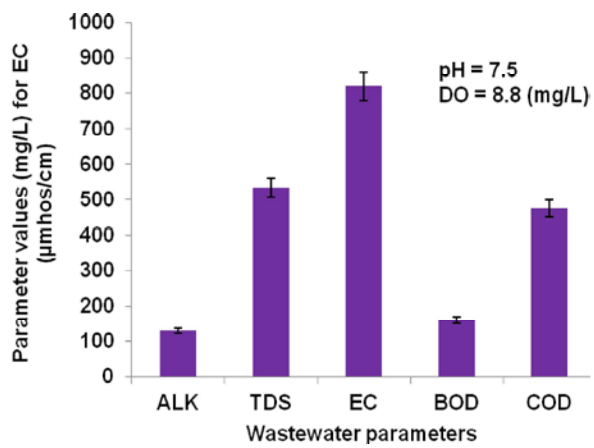

Fig. 2: Characteristics of treated wastewater.

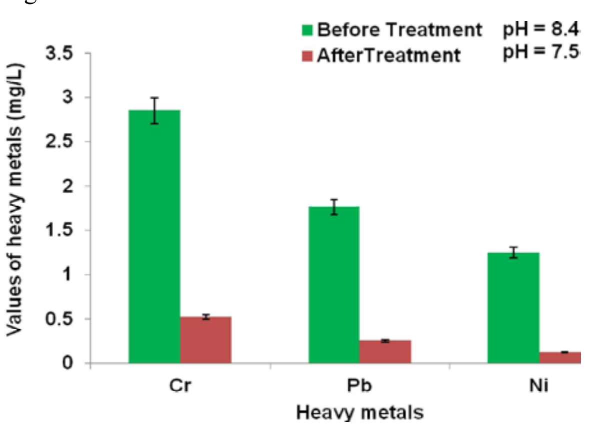

Fig. 3: Level of heavy metals in raw and treated wastewater.

Growth Characteristics of *Setaria glauca*: The treated wastewater is used for the growth of *Setaria glauca.* It is well observed that, within 120 days of time period, the grass is grown well. The individual grass is evaluated for its shoot and leaves length. The observation revealed that, the average shoot length is 95cm and leaves are grown in averages of 32cm. The total biomass weight is 2.5 kg per pot. This is clearly indicated that, the grass is steadily grown and producing good results. This is baseline data can be used for mass scale production of the fodder grass in a field. This green technology is two ways useful to the agriculturist; it will give good income to the farmers for the cattle's development and environmental conservation.

Policy Implication: The baseline data from the treatment of industrial wastewater and the development of fodder grass using the treated wastewater is a model trial and can be scientifically used for the irrigation of suitable crops and other leafy vegetables.

CONCLUSIONS

The following could be concluded from the obtained results.

- The nano-biocarbon technology is an efficient and sound technology for the treatment of industrial wastewater.
- It does not produce any major secondary effluent and sludge.
- Re-use of water can help to maximize the use of limited water resources.
- Wastewater re-use can contribute to national development.
- Environmental damage caused by re-use should be minimized.
- Health risks associated with re-use of water should be minimized.
- Collaboration between users, authorities and the public is needed.
- Exchange of experience is very important.
- Policies should be formulated to enhance safe use of wastewater for agriculture which will ultimately spare water for drinking and sanitation.

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