Water Science and Technology Library

Vijay P. Singh
Shalini Yadav
Ram Narayan Yadava *Editors*

# Water Quality Management

## Select Proceedings of ICWEES-2016

Springer

# Water Science and Technology Library

Volume 79

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# Preface

Fundamental to sustainable economic development, functioning of healthy ecosystems, reliable agricultural productivity, dependable power generation, maintenance of desirable environmental quality, continuing industrial growth, enjoyment of quality lifestyle, and renewal of land and air resources is water. With growing population, demands for water for agriculture and industry are skyrocketing. On the other hand, freshwater resources per capita are decreasing. There is therefore a need for effective water resources management strategies. These strategies must also consider the nexus between water, energy, environment, food, and society. With these considerations in mind, the International Conference on Water, Environment, Energy and Society (WEES-2016) was organized at AISECT University, Bhopal, Madhya Pradesh, India, from March 15 to 18, 2016. The conference was fifth in the series and had several objectives.

The first objective was to provide a forum to not only engineers, scientists, and researchers, but also practitioners, planners, managers, administrators, and policy makers from around the world for discussion of problems pertaining to water, environment, and energy that are vital for the sustenance and development of society.

Second, the Government of India has embarked upon two large projects one on cleaning of River Ganga and the other on cleaning River Yamuna. Further, it is allocating large funds for irrigation projects with the aim to bring sufficient good quality water to all farmers. These are huge ambitious projects and require consideration of all aspects of water, environment, and energy as well as society, including economics, culture, religion, politics, administration, law.

Third, when water resources projects are developed, it is important to ensure that these projects achieve their intended objectives without causing deleterious environmental consequences, such as waterlogging, salinization, loss of wetlands, sedimentation of reservoirs, loss of biodiversity.

Fourth, the combination of rising demand for water and increasing concern for environmental quality compels that water resources projects are planned, designed, executed, and managed, keeping changing conditions in mind, especially climate change and social and economic changes.

Fifth, water resources projects are investment-intensive, and it is therefore important to take a stock of how the built projects have fared and the lessons that can be learnt so that future projects are even better. This requires an open and frank discussion among all sectors and stakeholders.

Sixth, we wanted to reinforce that water, environment, energy, and society constitute a continuum and water is central to this continuum. Water resources projects are therefore inherently interdisciplinary and must be so dealt with.

Seventh, a conference like this offers an opportunity to renew old friendships and make new ones, exchange ideas and experiences, develop collaborations, and enrich ourselves both socially and intellectually. We have much to learn from each other.

Now the question may be: Why India and why Bhopal? India has had a long tradition of excellence spanning several millennia in the construction of water resources projects. Because of her vast size, high climatic variability encompassing six seasons, extreme landscape variability from flat plains to the highest mountains in the world, and large river systems, India offers a rich natural laboratory for water resources investigations.

India is a vast country, full of contrasts. She is diverse yet harmonious, mysterious yet charming, old yet beautiful, ancient yet modern. Nowhere can we find as high mountains as snowcapped Himalayas in the north, the confluence of three seas and large temples in the south, long and fine sand beaches in the east as well as architectural gems in the west. The entire country is dotted with unsurpassable monuments, temples, mosques, palaces, and forts and fortresses that offer a glimpse of India's past and present.

Bhopal is located in almost the center of India and is situated between Narmada River and Betwa River. It is a capital of Madhya Pradesh and has a rich, several century-long history. It is a fascinating amalgam of scenic beauty, old historic city, and modern urban planning. All things considered, the venue of the conference could not have been better.

We received an overwhelming response to our call for papers. The number of abstracts received exceeded 450. Each abstract was reviewed, and about two-thirds of them, deemed appropriate to the theme of the conference, were selected. This led to the submission of about 300 full-length papers. The subject matter of the papers was divided into more than 40 topics, encompassing virtually all major aspects of water and environment as well energy. Each topic comprised a number of contributed papers and in some cases state-of-the-art papers. These papers provided a natural blend to reflect a coherent body of knowledge on that topic.

The papers contained in this volume, "Hydrologic Modelling," represent one part of the conference proceedings. The other parts are embodied in six companion volumes entitled, "Energy and Environment," "Groundwater," "Environmental Pollution," "Water Quality Management," "Climate Change Impacts," and "Water Resources Management." Arrangement of contributions in these seven books was a natural consequence of the diversity of papers presented at the conference and the topics covered. These books can be treated almost independently, although significant interconnectedness exists among them.

This volume contains seven parts. The first part deals with some aspects of rainfall analysis, including rainfall probability distribution, local rainfall interception, and analysis for reservoir release. Part 2 is on evapotranspiration and discusses development of neural network models, errors, and sensitivity. Part 3 focuses on various aspects of urban runoff, including hydrologic impacts, storm water management, and drainage systems. Part 4 deals with soil erosion and sediment, covering mineralogical composition, geostatistical analysis, land use impacts, and land use mapping. Part 5 treats remote sensing and GIS applications to different hydrologic problems. Watershed runoff and floods are discussed in Part 6, encompassing hydraulic, experimental, and theoretical aspects. Water modeling constitutes the concluding Part 7. SWAT, Xinanjiang, and SCS-CN models are discussed.

The book will be of interest to researchers and practitioners in the field of water resources, hydrology, environmental resources, agricultural engineering, watershed management, earth sciences, as well as those engaged in natural resources planning and management. Graduate students and those wishing to conduct further research in water and environment and their development and management may find the book to be of value.

WEES-16 attracted a large number of nationally and internationally well-known people who have long been at the forefront of environmental and water resources education, research, teaching, planning, development, management, and practice. It is hoped that long and productive personal associations and friendships will be developed as a result of this conference.

College Station, USA — Vijay P. Singh, Conference Chair

Bhopal, India — Shalini Yadav, Conference Organizing Secretary

Hazaribagh, India — Ram Narayan Yadava, Conference Co-Chair

# Sponsors and Co-Sponsors

The International Conference on Water, Environment, Energy and Society was jointly organized by the AISECT University, Bhopal (M.P.), India, and Texas A&M University, Texas, USA, in association with ICE WaRM, Adelaide, Australia. It was partially supported by the International Atomic Energy Agency (IAEA), Vienna, Austria; AISECT University, Bhopal; M.P. Council of Science and Technology (MPCOST); Environmental Planning and Coordination Organization (EPCO), Government of Madhya Pradesh; National Bank for Agriculture and Rural Development (NABARD), Mumbai; Maulana Azad National Institute of Technology (MANIT), Bhopal; and National Thermal Power Corporation (NTPC), Noida, India. We are grateful to all these sponsors for their cooperation and providing partial financial support that led to the grand success to the ICWEES-2016.

# Acknowledgements

We express our sincere gratitude to Shri Santosh Choubey, Chancellor, and Dr. V. K. Verma, Vice Chancellor, Board of Governing Body, and Board of Management of the AISECT University, Bhopal, India, for providing their continuous guidance and full organizational support in successfully organizing this International Conference on Water, Environment, Energy and Society on the AISECT University campus in Bhopal, India.

We are also grateful to the Department of Biological and Agricultural Engineering and Zachry Department of Civil Engineering, Texas A&M University, College Station, Texas, USA, and International Centre of Excellence in Water Management (ICE WaRM), Australia, for their institutional cooperation and support in organizing the ICWEES-2016.

We wish to take this opportunity to express our sincere appreciation to all the members of the Local Organization Committee for helping with transportation, lodging, food, and a whole host of other logistics. We must express our appreciation to the Members of Advisory Committee, Members of the National and International Technical Committees for sharing their pearls of wisdom with us during the course of the conference.

Numerous other people contributed to the conference in one way or another, and lack of space does not allow us to list all of them here. We are also immensely grateful to all the invited keynote speakers and directors/heads of institutions for supporting and permitting research scholars, scientists and faculty members from their organizations for delivering keynote lectures and participating in the conference, submitting and presenting technical papers. The success of the conference is the direct result of their collective efforts. The session chairmen and co-chairmen administered the sessions in a positive, constructive, and professional manner. We owe our deep gratitude to all of these individuals and their organizations.

We are thankful to Shri Amitabh Saxena, Pro-Vice Chancellor, Dr. Vijay Singh, Registrar, and Dr. Basant Singh, School of Engineering and Technology, AISECT University, who provided expertise that greatly helped with the conference organization. We are also thankful to all the heads of other schools, faculty member and staff of the AISECT University for the highly appreciable assistance in different organizing committees of the conference. We also express our sincere thanks to all the reviewers at national and international levels who reviewed and moderated the papers submitted to the conference. Their constructive evaluation and suggestions improved the manuscripts significantly.

# Contents

# About the Editors

**Prof. Vijay P. Singh** is a Distinguished Professor, Regents Professor, Caroline and William N. Lehrer Distinguished Chair in Water Engineering, Department of Biological and Agricultural Engineering & Zachry Department of Civil Engineering, Texas A&M University, USA. He received his B.S., M.S., Ph.D., and D.Sc. degrees in engineering. He is a registered professional engineer, a registered professional hydrologist, and an Honorary Diplomate of American Academy of Water Resources Engineers.

Professor Singh has extensively published the results of an extraordinary range of his scientific pursuits. He has published more than 900 journal articles; 25 textbooks; 60 edited reference books, including the massive Encyclopedia of Snow, Ice and Glaciers and Handbook of Applied Hydrology; 104 book chapters; 314 conference papers; and 72 technical reports in the areas of hydrology, ground water, hydraulics, irrigation engineering, environmental engineering, and water resources.

For his scientific contributions to the development and management of water resources and promoting the cause of their conservation and sustainable use, he has received more than 90 national and international awards and numerous honors, including the Arid Lands Hydraulic Engineering Award, Ven Te Chow Award, Richard R. Torrens Award, Norman Medal, and EWRI Lifetime Achievement Award, all given by American Society of Civil Engineers; Ray K. Linsley Award and Founder's Award, given by American Institute of Hydrology; Crystal Drop Award, given by International Water Resources Association; and Outstanding Distinguished Scientist Award, given by Sigma Xi, among others. He has received three honorary doctorates. He is a Distinguished Member of ASCE and a fellow of EWRI, AWRA, IWRS, ISAE, IASWC, and IE and holds membership in 16 additional professional associations. He is a fellow/member of 10 international science/engineering academies. He has served as President and Senior Vice President of the American Institute of Hydrology (AIH). Currently, he is editor-in-chief of two book series and three journals and serves on editorial boards of 20 other journals.

Professor Singh has visited and delivered invited lectures in almost all parts of the world but just a sample: Switzerland, the Czech Republic, Hungary, Austria, India, Italy, France, England, China, Singapore, Brazil, and Australia.

**Prof. Shalini Yadav** is a Professor and Head of the Department of Civil Engineering, AISECT University, Bhopal, India. Her research interests include solid and hazardous waste management, construction management, environmental quality, and water resources. She has executed a variety of research projects/consultancy in environmental and water science and technology and has got rich experience in planning, formulating, organizing, executing, and management of R&D programs, seminars, and conferences at national and international levels. She has got to her credit guiding an appreciable number of M.Tech. and Ph.D. students. She has published more than 10 journal articles and 30 technical reports. Dr. Shalini has also visited and delivered invited lectures at different institutes/universities in India and abroad, such as Australia, South Korea, and Kenya.

Professor Shalini Yadav graduated with a B.Sc. in Science from the Bhopal University. She earned her M.Sc. in Applied Chemistry with specialization in Environmental Science from Bhopal University, and M.Tech. in Civil Engineering with specialization in Environmental Engineering from Malaviya National Institute of Technology, Jaipur, India, in 2000. Then she pursued the degree of Ph.D. in Civil Engineering from Rajiv Gandhi Technical University, Bhopal, India, in 2011. Also, she is a recipient of national fellowships and awards. She is a reviewer for many international journals. She has been recognized for one and half decades of leadership in research, teaching, and service to the Environmental Engineering Profession.

**Dr. Ram Narayan Yadava** holds position of Vice Chancellor of the AISECT University, Hazaribagh, Jharkhand. His research interests include solid mechanics, environmental quality and water resources, hydrologic modelling, environmental sciences, and R&D planning and management. Yadava has executed a variety of research/consultancy projects in the area of water resources planning and management, environment, remote sensing, mathematical modelling, technology forecasting, etc.

He has got adequate experience in establishing institutes/organizations, planning, formulating, organizing, executing, and management of R&D programs, seminars, symposia, conferences at national and international levels. He has got to his credit guiding a number of M.Tech. and Ph.D. students in the area of Mathematical Sciences and Earth Sciences. Dr. Yadava has visited and delivered invited lectures at different institutes/universities in India and abroad, such as USA, Canada, United Kingdom, Thailand, Germany, South Korea, Malaysia, Singapore, South Africa, Costa Rica, and Australia.

He earned an M.Sc. in Mathematics with specialization in Special Functions and Relativity from Banaras Hindu University, India, in 1970 and a Ph.D. in Mathematics with specialization in Fracture Mechanics from Indian Institute of Technology, Bombay, India, in 1975. Also, he is the recipient of Raman Research Fellowship and other awards. Dr. Yadava has been recognized for three and half decades of leadership in research and service to the hydrologic and water resources profession. Dr. Yadava's contribution to the state of the art has been significant in many different specialty areas, including water resources management, environmental sciences, irrigation science, soil and water conservation engineering, and mathematical modelling. He has published more than 90 journal articles; 4 textbooks; and 7 edited reference books.

# Part I
# Wastewater Treatment

# Investigation on the Treatment of Combined Effluent Treatment Plant Wastewater and Its Safe Use in Agriculture—A Green Technology Concept

**Malairajan Singanan**

**Abstract** Recent reports reveal that growing water scarcity and misuse of freshwater pose serious and growing threats to sustainable economic development, food security and protection of the environment. In developing countries, industrial sectors consuming most of the available freshwater for their productions. At the same time, it releases some wastewater into the environment and causes ecosystem damages. In the concept of environmental and economic sustainability, a proper wastewater management and water reuse system can help to a greater extent in development of national economy. Existing conventional water treatment technologies are costlier, and some are not eco-friendly in nature and consumes large amount of energy and produces secondary effluent. In this context, a new search for cheap and low-cost water purification technology is essential. The biocarbon material is generated using a novel medicinal plant, Garland daisy (*Glebionis coronia*—Asteraceae). The characteristics of the biocarbon are unique and having good potential for the removal of salts and organic components in water. As a model trial, a grey water system having heavy metal ions (Pb, Cr, Cu, Ni and Cd) of average concentration of 8.73 and 1800 mg/L of organic load was introduced in the reactor system; after equilibrium time of 3 h, the average concentration of heavy metal ions in outlet water is 0.57 mg/L, and the organic load of 360 mg/L is achieved at the biocarbon dose of 2.5 g/100 mL. The treated wastewater was introduced in the pilot agricultural system, where, *Setaria glauca,* a fodder grass and Sorghum crop were grown well. These results suggest that new biocarbon technology is a promising option for wastewater treatment. The treated water can be reused for various purposes in industries as well as in agricultural development and help to prevent the misuse of available freshwater resources.

**Keywords** Garland daisy · *Glebionis coronia* (L) · Biocarbon
Wastewater reuse · Agriculture practices

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## Introduction

Water is a critical component in the functioning of the earth and of all living forms of life. Raising human population and industrialization has increased tremendous pressures on global freshwater resources and resulting growing water consumption and pollution, in combination with the impacts of climate change. In many arid and semi-arid regions of the world, the availability of freshwater is very much limited. In such situations, wastewater reuse has become an acceptable part of the water supply system in many parts of the world. While water reuse has the potential to improve water usage and protect and preserve global freshwater resources, also it should be taken into the account of possible environmental and health risk facts associated with the wastewater reuse (Mapanda et al. 2005; Oghenerobor et al. 2014).

There are several contaminants in wastewater, with organic pollutants playing the major role. Toxic organic pollutants cause several problems to the environment. The most common organic pollutants are persistent organic pollutants (POPs). POPs are compounds of great concern due to their toxicity, persistence, long-range transport ability (Harrad 2001) and bioaccumulation in animals (Burkhard and Lukazewycz 2008). The presence of colour and colour-causing compounds has always been undesirable in water for any use. It, therefore, need to be treated before discharge (George et al. 2013; Ali et al. 2012; Abdel-Ghani et al. 2016).

In addition, the toxic heavy metals are also the major contaminant in industrial wastewater. The metals commonly include cadmium (Cd), lead (Pb), copper (Cu), zinc (Zn), nickel (Ni) and chromium (Cr). These metals enter into human bodies either through direct intake or through food chains (Argun and Dursun 2008; Ghanbari and Shahram 2016). Due to toxicity and cumulative effects, these pollutants impose destructive effects on environment and ultimately human into the threat of toxicity, cancer and long-term and short-term genetic effects (Gholamreza and Mehrzad 2016). The aim of water reuse for agriculture is to promote ecologically sustainable development, protection of environment by pollution and protection of public and community health. Reusing the treated wastewater is becoming more valuable resources for industrial, agriculture practices and other domestic uses.

The greater environmental awareness among public in recent years and the demand for clean environment have necessitated the treatment of industrial effluent. As such there has been a great deal of research into finding cost-effective methods for the removal of contaminants from wastewater. In recent years, considerable attention has been devoted to the study of removal of heavy metal ions from solution by adsorption (Bohli et al. 2012; Abdul et al. 2014; Taik-Nam and Choong 2013).

Many physico-chemical methods have been proposed for their removal from industrial effluents. Adsorption is an effective purification and separation technique used in industry especially in water and wastewater treatments (Guixia et al. 2011; Bernard et al. 2013). Sorption technique is a commonly used method for the treatment of various industrial effluents (Naseem 2012; Hala 2013). Numbers of cheaper materials, including soil, silica, activated carbon, green coconut shell and others, have been used to remove different pollutants from industrial effluents for their safe disposal into the biosphere (Mahmoodi et al. 2011; Kumar and Meikap 2014). Biosorption is a relatively new process that has been proven very promising in the removal of contaminants from aqueous effluents using low-cost adsorbents derived from agricultural materials (Nomanbhay and Palanisamy 2005).

In this study, an attempt was made to use the leaves of Garland daisy *(Glebionis coronia*—Asteraceae) for the preparation of biocarbon for the potential removal of colour and toxic heavy metals from industrial wastewater. The treated industrial wastewater is applied in pilot scale for cultivation of Sorghum crop and *Setaria glauca,* a fodder grass for livestock applications. The selected medicinal herb is found in agricultural fields in Tamil Nadu, India, throughout the seasons. The present work investigates the potential use of biocarbon of Garland daisy *(Glebionis coronia*—Asteraceae) for biosorption of organic and inorganic pollutants from a combined effluent treatment plant (CETP) wastewater. The factors that influence biosorption capacity such as pH, contact time, metal ion concentration and biocarbon dosage were evaluated.

## Materials and Methods

### *Preparation of Biocarbon*

**Garland daisy** *(Glebionis coronia*—Asteraceae) is an important medicinal plant widely distributed in agricultural fields. The plant leaves were collected and air-dried for 48 h. The dried leaves were grounded in ball mills, and the screened homogeneous powder was used for the preparation of biocarbon. The activated biocarbon was prepared by treating the leaves 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, then dried at 105 ± 5 °C. The particle size of activated carbon between 100 and 120 μm was used (Singanan 2015).

### *Collection and Analysis Grey Water*

The grey water samples were collected from a combined effluent treatment plant (CETP) of metal plating and distillery effluents from an industrial area located in

Tamil Nadu, India. The important physico-chemical characteristics such as pH, EC, alkalinity, SS, TDS, EC, DO, BOD, COD and heavy metals mainly for Pb, Cr, Cu, Ni and Cd were performed by using standard methods outlined in APHA manual (APHA 1985). The level of metal ions content in grey water was analysed using Shimadzu AAS 6200 instrument with air–acetylene flame system.

## *Treatment of Grey Water: Biosorption Process*

The grey waters collected from CETP plant were passed through the specific screening system for the removal any dirt materials. A dirt-free grey water samples were collected in clean polythene containers and subjected to batch biosorption process with pre-defined equilibrium data. The biosorption process was carried out at the room temperature of 28 ± 2 °C in a series of six 250 mL capacity Erlenmeyer flask. Each flask is loaded with 100 mL of wastewater and subjected to equilibrium process. The wastewater treatment process and reuse for cultivation operation were illustrated in Fig. 1.

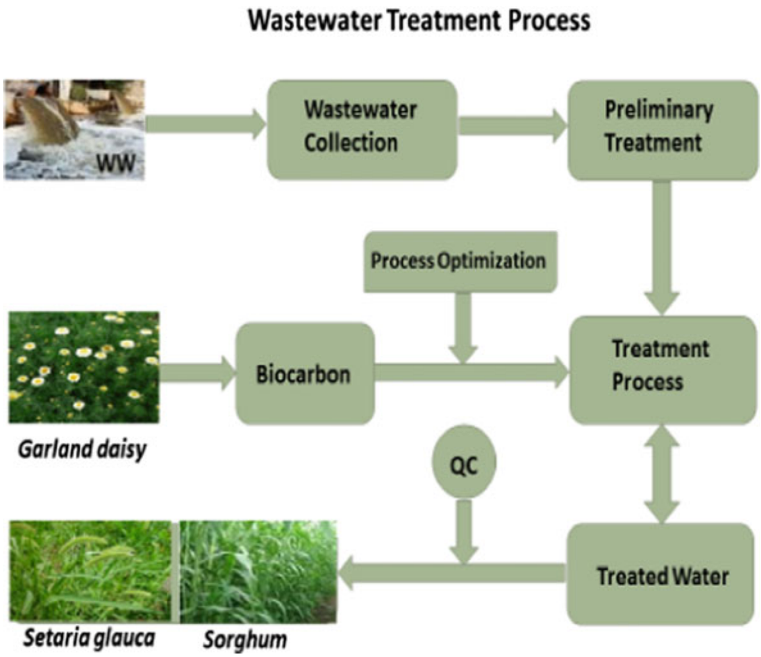


**Fig. 1** Wastewater treatment and reuse for cultivation process

### *Evaluation of Capacity of Biocarbon*

The evaluation of treatment capacity of biocarbon was carried out as follows: 100 mL of grey water sample was used in each biosorption flask containing 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5 and 4.0 g biocarbon dose. All the flasks were equilibrated using Remi orbital shaker system at 250 rpm for the contact time of 150 min. At the end of equilibrium time, samples were collected, and respective concentration of heavy metal ions present in the wastewater is determined using AAS. 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 are obtained and used for the discussion of findings.

### *Data Analysis*

Biosorption values were determined as the difference between the initial heavy metal ion concentration in raw wastewater and that in the treated wastewater. The amount of heavy metal ions adsorbed per unit mass of the biosorbent was evaluated by using the following equation:

$$q_e = \left(\frac{C_o - C_e}{w}\right) \times V \tag{1}$$

where $q_e$, amount of heavy metal ions adsorbed (mg/g); $V$, volume of heavy metal ions in solution (mL); $w$, mass of biocarbon (g); $C_o$, initial heavy metal ion concentration (mg/L); $C_e$, heavy metal ion concentration at equilibrium (mg/L). The percent removal of heavy metal ions was evaluated from the equation:

$$\%\ \text{Removal} = \left(\frac{C_o - C_e}{C_o}\right) \times 100 \tag{2}$$

The analytical data were analysed, and standard deviations of the statistical tests were carried out using the programme of analysis of variance (ANOVA) by using SPSS program.

## Results and Discussion

### *Characteristics of Biocarbon (BC)*

The nature and the characteristics of the biocarbon are essential to understand the adsorptive behaviour on the surface of the biocarbon. The detailed characteristics of the biocarbon of Garland daisy *(Glebionis coronia)* are reported in Table 1. It is observed that the surface and particle size are relatively high and are responsible for potential removal of metal ions and organic molecules from grey water system. The result indicates that the biocarbon has high capacity for metal ion adsorption, and it is regenerative in nature.

## *Surface Analysis*

Information on the morphological features of the adsorbents in wastewater treatment system is very much important. It mainly reveals the possible mode of biosorption process and its regenerative nature of adsorbents. To investigate surface condition for before and after adsorption of metal ions and organic pollutants, SEM photograph and EDX spectrum were used. The SEM picture shows the presence of number of microcavities and canal-like structures. As shown in Fig. 2a, b, electron dense part which is thought to be metal ion present in the effluent was appeared at the SEM (b) as compared with SEM (a).

## *Characteristics of Grey Water and Treated Water*

The analytical results of physico-chemical characteristics of raw grey water and treated grey water have been evaluated and presented in the Table 2. It indicates that the grey water is highly contaminated with heavy metals and organic pollutants which accelerate the higher level of COD in the grey water system. Higher organic load is mainly contributing the rise in biological oxygen demand (BOD) of the wastewater.

**Table 1** Characteristics of the biocarbon

| S. No. | Parameters | Values for BC |
|---|---|---|
| 1 | Moisture content | 0.40% |
| 2 | Ash content | 8.75% |
| 3 | Total carbon | 92.5% |
| 4 | Bulk density | 1.35/mL |
| 5 | Matter soluble in water | 0.60% |
| 6 | Matter soluble in acid | 1.5% |
| 7 | pH | 7.30 |
| 8 | Ion exchange capacity | 0.95 meq/mg |
| 9 | Methylene blue value | 35 |
| 10 | Phenol number | 48.5 |
| 11 | Decolourizing power | 1.50 mg/g |
| 12 | Iron | 0.82% |
| 13 | Surface area | 385 $m^2$/g |

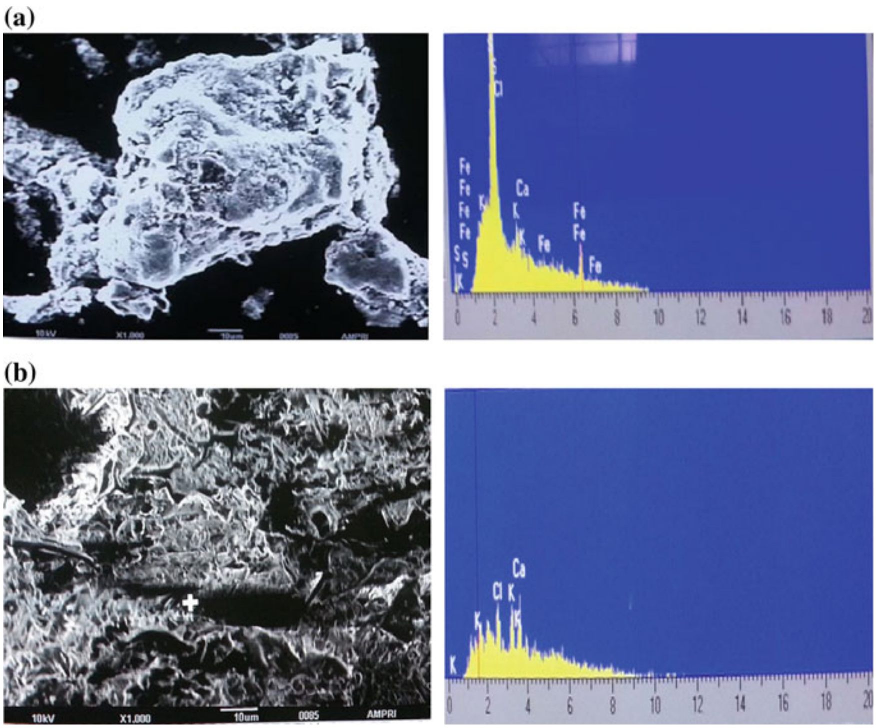


**Fig. 2** **a** SEM photograph and EDX spectrum of biocarbon—before adsorption. **b** SEM photograph and EDX spectrum of biocarbon—after adsorption

**Table 2** Characteristics of CETP grey water

| S. No. | Characteristics of grey water | Quality of grey water (mg/L) | | Percent reduction |
|---|---|---|---|---|
| | | Before treatment | After treatment | |
| 1 | pH | 8.5 | 6.7 | 21.17 |
| 2 | EC (μmhos/cm) | 2080 | 485 | 76.68 |
| 3 | Alkalinity | 955 | 275 | 71.20 |
| 4 | Suspended solids | 1125 | 220 | 80.44 |
| 5 | Total dissolved solids | 1350 | 315 | 76.66 |
| 6 | Dissolved oxygen | 4.2 | 5.8 | – |
| 7 | Total nitrogen | 145 | 35 | 75.86 |
| 8 | Total phosphorous | 120 | 30 | 75.00 |
| 9 | BOD | 640 | 120 | 81.25 |
| 10 | COD | 1800 | 360 | 80.00 |
| 11 | Pb | 10.5 | 0.75 | 92.85 |
| 12 | Cr | 12.5 | 0.65 | 94.80 |
| 13 | Ni | 8.55 | 0.58 | 93.21 |
| 14 | Cu | 6.40 | 0.35 | 94.53 |
| 15 | Cd | 5.70 | 0.50 | 91.22 |

The results indicate that the biocarbon technology works well, and all the parameters are significantly reduced. The dark colour of grey water was well reduced to almost colourless. The main pollution parameter such as COD and BOD is reduced to 80–81.25%, respectively. Alkalinity of the wastewater is 71.20% reduced making the water suitable for crop irrigation. Relatively, the level of TDS is good in treated wastewater. The level of heavy metals such as Cr and Pb is high in the grey water. It will definitely cause toxic effects in humans and animals when using this grey water for any irrigation purpose. After the treatment process, the concentration of heavy metals is well reduced as Pb (92.85%), Cr (94.80%), Ni (93.21%), Cu (94.53%) and Cd (91.22%) and is within the agricultural quality of wastewater. The analytical results support that the biocarbon has excellent biosorption capacity to the removal of heavy metals and the organic pollutants in grey water system.

## Effect of Biocarbon Dose on Heavy Metals Removal

The amount of biocarbon dose was a key parameter to control both availability and accessibility of adsorption sites in the sorption process of heavy metal ions present in the wastewater (Rafeah et al. 2009). The effect of biocarbon dosage on the removal of Pb(II) and Cr(VI) ions as representative species in the wastewater is presented in Fig. 3. The per cent removal of metal ions has reached up to 92.5 and 94.8 for both Pb(II) and Cr(VI), respectively, at the biocarbon dose of 2.5 g/100 mL. The results indicate that the higher dosage of adsorbent will increase the adsorption due to more surfaces, and functional groups are available on the biocarbon matrix.

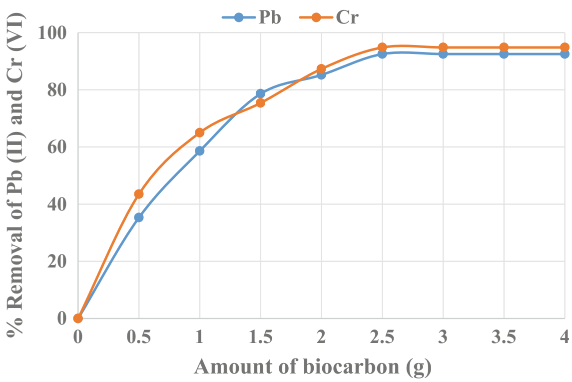


**Fig. 3** Effect of biocarbon dose on the removal of Pb(II) and Cr(VI)

## Removal of Colour from a Grey Water

The removal of colour from grey water was performed with the initial concentration of 800 mg/L (100%) with optimum biocarbon dose of 2.5 g/100 mL. An excellent result (95.0%) of colour removal is achieved in 150 min (Fig. 4). These results suggest that new biocarbon technology is a promising option for water and wastewater treatment.

## Water Reuse in Agriculture Practice

The treated industrial wastewater is applied in pilot scale for cultivation of Setaria glauca, a fodder grass for livestock applications, and Sorghum for small-scale irrigation shown in Fig. 5. The productive results are presented in Table 3. The results demonstrated that the treated grey water has good nutrient capacity and hence, the species is steadily grown well and produced good yield.

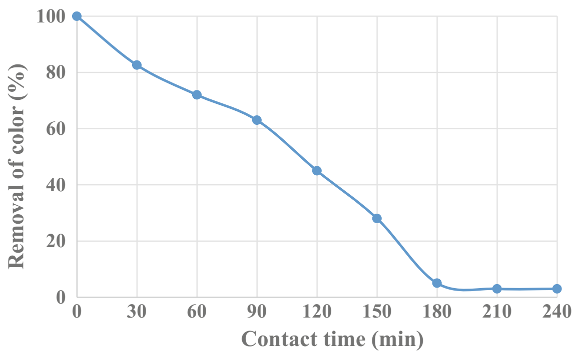


**Fig. 4** Effect of contact time on colour removal

(Setaria glauca) (Sorghum)

**Fig. 5** Cultivation of *Setaria glauca* and Sorghum

**Table 3** Growth characteristics of *Setaria glauca* and Sorghum

| S. No. | Parameters | *Setaria glauca* | Sorghum |
|---|---|---|---|
| 1 | Field size | 12 × 12 sq. ft. | 12 × 12 sq. ft. |
| 2 | Growth period | 120 days | 120 days |
| 3 | Total biomass | 3.0–4.0 kg/sq. ft. | 3.5–4.5 kg/sq. ft. |

## Conclusion

The toxic inorganic and organic pollutants (POPs) in the ecosystem are of the most important environmental concerns in the world. An eco-friendly and most efficient technologies for the removal of highly toxic contaminants from wastewater have drawn significant interest in recent times. Biosorption is recognized as an effective and low-cost technique for the removal of industrial pollutants from water and wastewater and produces high-quality treated wastewater. It is also found that there is a certain limit for increasing the biosorbent doses for given amount of wastewater. This has to be carefully controlled. An excess use can lead to uneconomical process. The initial concentration plays an important role throughout the biosorption. With the experimental data obtained in this study, it is possible to design and optimize an economical treatment process for the removal of various pollutants from industrial wastewater. The biocarbon technology is an efficient and economically sound technology for the treatment of industrial grey water and does not produce any major secondary effluent and sludge. The treated water can be reused for various purposes in industries as well as in agricultural development. In the present pilot scale study, the yield of fodder grass *Setaria glauca* and *Sorghum* is confirmed as good, and also further revealed that the biocarbon-treated wastewater is much useful for irrigation for cultivation of plants by reuse technology and imposes to save the environment from pollution-causing agents.

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