Ramakrishna Memorial Award

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Ramakrishna Memorial Award - 2020

From biomass to biochar: A potential means of solid waste management in Sri Lanka

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Biochar (BC) is a carbonaceous adsorbent that is produced by the thermal decomposition of organic biomass under oxygen-deficient conditions. This process is commonly termed pyrolysis. The recalcitrant carbon pool of BC contributes to its longevity, making it resistant to decomposition and its porous features make it an excellent adsorbent. Therefore, BC has gained widespread acclaim as an agricultural soil amendment and in pollution remediation schemes. Three factors govern the characteristics of BC; feedstock type, pyrolysis conditions, and physical and chemical value additions incorporated. The value addition of BC can result in either an increase in surface sorption sites or an elevated porosity. The surface area can also be increased as a result of demineralization and removal of trapped constituents in the feedstock. A chemist's contribution towards manipulating these factors becomes vital if optimum features of the BC are to be harnessed.

Being the fourth-largest producer of tea in the world and the second-largest exporter, Sri Lanka generates a significant amount of tea-waste. A harmful repercussion of this is the adulteration of our authentic tea. With the aid of existing literature, a possible direction in waste management, which was to use tea-waste as a viable feedstock for BC production, was explored. In doing so, a substantial contribution has been made to the knowledge hub on prevailing methods of solid waste management in not only Sri Lanka, but the world at large. By nature, tea-waste biochar (TWBC) has a low pore size as compared to most of the other frequently used BC types. Hence, its adsorption capacity is not very high. Researchers worldwide have conducted studies to incorporate modifications to TWBC to enhance its adsorption capacity for a specific analyte. However, a research gap is created as no comprehensive study has been done to evaluate how value additions influence the physicochemical properties of BC. The work titled "The influence of three acid modifications on the physicochemical characteristics of tea-waste biochar pyrolyzed at different temperatures: a comparative study", was an initiative to bridge this gap. Three of the most common types of acid modifications were selected and a comparison was established between the changes in physicochemical characteristics that took place upon modification of the TWBC. The effect of pyrolysis conditions were also evaluated by producing BC at three different temperatures. This systematic comparison will aid in the preliminary planning of any study related to TWBC. The research was published in RSC Advances having an impact factor of 3.049 and an intellectual contribution was made as the corresponding author of the publication. Eighty percent of the bench work related to the study was carried out at the IChemC premises.

It becomes essential that the metallic composition of a carbonaceous adsorbent is known for an effective adsorption study to be carried out. Even though Energy-dispersive X-ray spectroscopy (EDX), X-ray diffraction (XRD) and X-ray photoelectron spectroscopy (XPS) are available for the determination of metal composition, these techniques can only give an idea of the surface elemental composition of the BC. To get a better picture of the metallic components in the entire BC sample, it has to be digested. Many EPA methods are reported for the digestion of matrices that are siliceous, organic-based, and sludge-based. However, the standard EPA methods defined for the digestion of biomass-based carbonaceous adsorbents, such as BC, were inadequate and were associated with several discrepancies. The time taken and the hazards associated with the reagents used to obtain complete digestion made the existing

techniques for BC digestion unfavorable. The objectives that the work on "Microwave and open vessel digestion methods for biochar" coveted to achieve were two-fold. Firstly, a relatively fast and simple open vessel digestion technique for the digestion of BC was to be developed. Secondly, a novel method for the digestion of BC using the microwave digester was to be established by a trial and error method. These objectives were successfully achieved and the work was published in Chemosphere which carried an impact factor of 5.108. In this study, a contribution was made as the corresponding author of the publication and it must be stated that all the bench work related to the research was carried out using the research facility at IChemC.

The strong scientific network that has been maintained within Sri Lanka and among eminent scientists from abroad opened up the remarkable opportunity of contributing to important research projects related to BC. Solid waste management is a definite problem in the current context of Sri Lanka and recently, there has been much focus on the disposal of municipal solid waste (MSW). Garbage generated mainly from household wastes can lead to the production of harmful landfill gases. The landfill gas can contain harmful volatile organic compounds (VOCs) such as benzene, toluene, ethylbenzene, and xylene. Pyrolysis is a technique popularly used to manage such solid wastes. A timely initiative was taken to remediate VOCs released from landfill gas by using MSW derived BC. A contribution was made in a research project which was done in collaboration with Sri Lankan researchers who were actively engaged in BC research. The work was titled "Sorptive removal of toluene and m-xylene by municipal solid waste biochar: Simultaneous municipal solid waste management and remediation of volatile organic compounds" and was published in the Journal of Environmental Management which bears an impact factor of 4.175. The magnetization of BC is an important value addition that enables the rapid and easy retrieval of exhausted BC from aqueous media. Douglas fir is a highly porous BC produced as a byproduct of gasification. A magnetization step has been incorporated to this BC for the adsorption of Arsenic and phosphate from water. Arsenic can exist under different oxidation states in the environment and its remediation from aqueous media using BC was less studied. A comprehensive study on the mechanisms of As(III) adsorption and the redox effects of As(III) to As(V) on magnetite surfaces were evaluated in the study "Removal of As(III) from water using magnetite precipitated onto Douglas fir biochar" which was published in the Journal of Environmental Management. Phosphate, even in concentrations as low as 100 µg/L, can cause eutrophication. Remediation techniques studied for phosphate are still in its preliminary stages and the work "Fe_3O_4 Nanoparticles Dispersed on Douglas Fir Biochar for Phosphate Sorption" is a noteworthy contribution made towards the progress in this field. Studies related to pH optimization, kinetic studies, and isotherm modeling were done at the Institute. Contribution was made to each of these publications as a co-author.

Magnetic BC has been made with tea-waste and kohila (*Lasia Spinosa*) as well. These projects were conducted as Undergraduate research projects. Magnetized TWBC was utilized for the adsorption of cadmium, lead and copper from aqueous media and the magnetized kohila BC was used for the adsorption of methylene blue, which is a synthetic organic dye. Moreover, when considering the use of BC in agriculture, there is no literature to support the use of modified TWBC as an agricultural soil amendment. To evaluate the influence that acid-modified TWBC had on soil health and soil nutrients cycling, modified TWBC was applied in a greenhouse experiment involving the growth of Red Onions. The research was done in fulfillment of an MPhil project where guidance and intellectual support was rendered as the principal supervisor. Additionally, the groundwork for a chemical education research is also in progress. Biochar is usually produced inside a muffle furnace. However, considering the widespread acclaim of pyrolysis, it becomes important to introduce a simpler method of BC production. This experiment is mainly targeted at imparting knowledge on pyrolysis to high school students so that they can produce BC using minimum facilities. The work described has produced promising results and the manuscripts for each are still in preparation.

A significant contribution has been made for the dissemination of knowledge related to BC, its application and mechanistic approaches. Even though much research is conducted globally, knowledge related to specific topics tends to remain scattered. The article "Biochar Based Removal of Antibiotic Sulfonamides and Tetracyclines

in Aquatic Environments: A critical review" was aimed at bringing the detailed mechanisms associated with the adsorption of sulfonamides and tetracyclines to one place. In doing so, knowledge on the variety of ways that different functionalities on the BC surface interacted with other organic functionalities have been discussed. The article was published in Bioresource technology which had an impact factor of 5.807. This review gained the limelight as the first article to be published under the Institute address to achieve the Presidential award for scientific research in Sri Lanka and currently, it has more than a hundred citations in Google Scholar. Furthermore, a book chapter titled "Biochar for Sustainable Agriculture: Nutrient Dynamics, Soil Enzymes, and Crop Growth" was written for the book "Biochar from Biomass and Waste". Furthermore, going beyond the comfort zones of analytical, physical and environmental chemistry, a book chapter on the "Determination of steroidal estrogens in food matrices: current status and future perspectives" was published for "Current Opinion in Food Science". The review on "Recent advancements in analytical methods for the determination of steroidal estrogen residues in environmental and food matrices" was the debut publication under the Institute address. A chapter on the "Phytoremediation for E-waste contaminated sites" which was written for the "Handbook of Electronic Waste Management" has been published as well. An area that is gaining significant interest is the remediation of particulate plastics. An attempt was made to coalesce the scattered knowledge on different analytical remediation methods that existed for microplastics. The book chapter titled "Analytical methods for particulate plastics in soil and water" for the book "Particulate Plastics: Sources and Eco-toxicity in Terrestrial and Aquatic Environments" has been accepted and is currently with its publisher, the CRC press.

Thus far, having published fifteen research articles, having supervised over twelve undergraduate projects, and one MPhil study, and serving as a reviewer in several acclaimed peer-review journals, a prominent contribution has been made towards the development of rational thinking skills of students and to the scientific knowledge hub.

Dr Sameera Ranmal Gunatilake *obtained the GIC qualification from the Institute of Chemistry Ceylon and the PhD from Mississippi State University, Mississippi State, USA. He is currently serving as a Senior Lecturer at the College of Chemical Sciences, Institute of Chemistry Ceylon.*

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