Research Into Removal of Nutrients and Chlorides from Swan Lake

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Removal of Nutrients (N and P) and Chlorides from Swan Lake Water

1. Introduction:

Nitrogen (N) and phosphorus (P) are essential elements for many important life processes such as protein and DNA synthesis, primary production, cellular growth, and reproduction for both plants and animals that make up the aquatic food web[1,2]. Both elements are critical nutrients for crop productivity and are largely responsible for ensuring adequate food, fiber, and shelter for the growing human population[3]. To meet the demands of the current population excessive use of nutrients are in use to grow food leading to nutrient surpluses and mismanagement of nutrients in developed countries and developing countries, respectively[4,5]. Surface water receives water from municipal sewage treatment plants, runoff from fertilized lawns and cropland, failing septic systems, runoff from animal manure storage areas, and industrial wastewater. Hence, excessive usage of these nutrients has resulted in losses of nutrients from land (urban and agricultural runoff) to water bodies[6]. A modest increase in P and N can cause undesirable events including accelerated plant growth, algae bloom (eutrophication), low dissolved oxygen, and the death of certain fish, invertebrates, and other aquatic animals[7].

Apart from these nutrients, Chlorides are very common water pollutants, especially in Canada[8]. The Canadian industries produced 10 million metric tonnes of salt in 2021 and nearly three-quarters of this total is rock salt used primarily for highway de-icing[9], [10]. Surface runoff of this salt serves as the primary anthropogenic source of chloride to the receiving water bodies apart from industrial chemicals and fertilizer from agriculture such as sodium chloride, and potassium chloride, respectively. Like N and P, Chloride is an essential element for maintaining proper osmotic pressure, water balance, and acid-base balance in aquatic and terrestrial ecosystems[11]. Increased chloride concentrations can induce a variety of environmental effects such as acidification of streams, effect on mortality and reproduction of aquatic plants and animals, inhibit the process of denitrification, the microbial process, that's critical for removing nitrate and maintaining water quality[12].

Over the past decades, significant progress has been made towards our understanding of the dynamics of anthropogenic inputs of N, P, and Cl^- and the development of various removal techniques from the receiving water bodies[13,13–15]. Furthermore, the recognition of enormous amounts of N, P, and Cl^- inputs by humans has driven much research into the scope for better management of these nutrients. In this project, we are proposing the adsorption technology using biochar produced from Char technologies to remove all three nutrients from Swan Lake water. Based on the characteristics of the lake water, biochar adsorption technology will be developed and tested on a lab-scale to understand the critical parameters to achieve optimal efficiency.

2. Objectives:

The global objective of this project is to "Development of biochar adsorption techniques to remove nutrients from Swan Lake and its scale-up. The specific objectives are:

Objective 1. Adsorption removal of nutrients (N, P, and Cl^-) from Swan Lake water

- 1.1 Characterization of Swan Lake water
- 1.2 Biochar utilization for the removal of nitrogen, phosphorus, and chloride nutrients

Objective 2. lab-scale units to test the biochar efficiency on the removal of selected nutrients

3. Methodology:

Objective 1. Removal of nutrients (N, P, and Cl^-) from Swan Lake water

3.1 Characterization of Swan Lake water: Nearly, one-month Swan Lake samples (twice a week) will be collected to monitor the existing concentration of selected nutrients in the surface water. Apart from the N, P, and Cl^-, other physical and chemical characterization of water samples such as total dissolved solids, pH, dissolved oxygen, total suspended solids, chemical oxygen demand, conductivity, and heavy metals will be measured as per standard methods[16].

3.2 Biochar utilization for the removal of nutrients

Biochar is produced by the CHAR Biocarbon Inc. organization from wood residues and will be used in this project. The biochar will be received from CHAR as a complimentary for this project. The received biochar sample will be ground and sieved to obtain uniform biochar microparticles 1-100 μm with an increased surface area. The treated biochar samples will be dried at 60 °C overnight and used for the adsorption removal of nutrients. Further, characterization (size analysis, porosity, pore distribution, ash, and moisture content) of processed biochar will be carried out as per ASTM methods described in the studies of Brar's group[17].

3.2.1 Adsorption capacity of biochar for Nutrients: The processed biochar will be subjected to adsorption studies of selected Nutrients in the collected lake samples. To find the adsorption efficiency, two types of tests will be carried out: (1) The optimization of the biochar weight at a constant concentration of each nutrient (10 mg; this will be determined based on the objective 1) individually and in combination; (2) Optimization of concentrations of nutrients 5-100 mg for a constant weight of biochar obtained from test 1. Once the optimization of biochar weight and its efficiency was determined, collected lake samples will be used to test the removal efficiency of biochar in real samples. All the experiments will be conducted at constant pH (surface water pH) and agitation speed (150 rpm) for 24h in an incubator shaker at 25 ± 1 °C and in triplicates. After incubation, the mixture of biochar and nutrient suspensions will be centrifuged, and the clear supernatant will be used for estimating the concentration of the un-adsorbed nutrient by the methods used in objective 1[18].

Objective 2. Lab-scale unit to test the biochar efficiency

Bench-scale testing will be performed as rapid small-scale column tests (RSSCTs) to validate the performance of biochar. This approach is critically important before going for the pilot- and full-scale surface water treatment, to evaluate how real water conditions (e.g., dissolved organic carbon, pH), and water constituents (e.g., organic matrix, residual chlorine for drinking water) impact the overall nutrients removal[16].

Lab-scale filter: The optimized biochar weight obtained from *objective 2.2* will be further used to develop a lab-scale filter, a rapid small-scale column test (RSSCTs). RSSCT setup: Column experiments will be conducted using a glass column (1 cm inner diameter, 20 cm long) packed with biochar (2 g and 5 g) and sealed with glass pearls/glass wool and glass beads to hold the biochar frameworks in place. This type of packing will give compactness to the adsorbent (i.e. MBEFs). Dr. Brar's group has already conducted biochar-packed column tests to study the removal of trace contaminants[19]. The collected lake samples spiked with selected nutrients, 10 mg (each N, P, and Cl^-) will be pumped through the column using a peristaltic pump. Various nutrient concentrations (1 – 10 mg/g) at a different flow rate (1- 5-mL/min) for all nutrients will be tested for 24 h and the collected samples will be analyzed for residual nutrients as per *Objective 1*.

Performance indicators: For the lab-scale filter, indicators such as the loading behavior of biochar will be expressed in terms of the normalized concentration C_0/C_t (where C_0 and C_t are the inlet and outlet (at time t) of nutrient concentrations, respectively) for a given mass of biochar (bed height). Other performance indicators such as equilibrium uptake of the column, the total amount of nutrient adsorbed, and removal percent of nutrients will be determined as per our previous studies.
Column regeneration: Chemical regeneration methods will be adopted from the literature. Briefly, the used biochar will be equilibrated in a mechanical shaker for 1 h with sodium chloride and HCl for biochar recovery.

4. Project budget:

Timeline: We suggest using a Gantt chart to provide a timeline showing which task will be done when to achieve each objective

Research goals	**July – August 2022**	**September-October 2022**	**November-December 2022**
Project initial meeting at York University	York University		
1. Removal of nutrients (N, P, and Cl-)			
1.1 Characterization of Swan Lake water			
1.2 Biochar utilization for the removal of nutrients			
2. Lab-scale units to test the biochar efficiency			

Expenditure:

Expenditure type	July-August 2022	September-October 2022	November - December 2022	Total
Salaries and Wages				
Research Associate	2,500	3,000	4,000	**9,500**
Student	500	1,500	1,500	**3,500**
Project Management and corodination	250	500	500	**1,250**
Professional service expenditure (Lab analysis)	2,500	3,500	3,500	**9,500**
Field service (sampling and travel)	750	1,000	1,000	**2,750**
Subtotal of Salaries and benefits	6,500	9,500	10,500	**26,500**
Material and supplies expenditure				
Lab consumables and supply	3,000	3,000	3,500	**9,500**
Subtotal of Material and supplies expenditure	3,000	3,000	3,500	**9,500**
University overhead (20% of total)				
Overhead (20%)	1,900	2,500	2,800	**7,200**
Total Budjget	11,400	15,000	16,800	**43,200**

Deliverables:

Objective 1: Optimization of biochar weight as per Swan Lake characteristics to remove the selected nutrients
Objective 2: Verifying the efficiency of the lab-scale biochar-based filter for the removal of the nutrients

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Prof. Satinder K Brar

Dr. Brar has an H-index of 65 and is a nationally and internationally recognized researcher with exceptional expertise in the two converging fields of value-addition of wastes and removal of emerging contaminants. Her research has transcended frontiers and is now adapted all around the world. For example, her research on biopesticides and biofertilizers using wastewaters is now applied in Vietnam, Morocco, Ivory Coast, Thailand, Mexico, and India. In fact, she is frequently invited to give talks in different international forums and conferences, about the wide-ranging subject of applied biotechnology. For example, she was invited by German, Mexican, Indian and Chinese Academy of Sciences to share her experiences on solid waste value-addition and the fate of emerging contaminants. She has been counted amongst the most outstanding and innovative world-class researchers whose accomplishments have made a major impact in her field. She has been invited by different grant agencies worldwide (including France, Switzerland, Spain, Germany, Poland, Austria, Malaysia, Australia, US, Taiwan, Hong Kong, India, among others) as a reviewer and expert in panels that talk volumes about her exceptional research prowess and expertise.

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Experienced analytical chemist with a demonstrated history of working in analytical laboratories and developing validated methods for pharmaceuticals and other organic compounds. Water treatment scientist with a strong background in water treatment methods, contaminant fate and transport, site remediation, data collection and management. Skilled in chemistry, Good Laboratory Practice (GLP), chromatographic techniques, mass spectrometry, elemental analysis, development & validation of analytical methods. Strong Pharmacy and Chemistry professional background.