

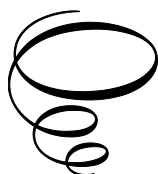
Greening the Future through Chemical Resilience and Sustainable Practices

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Edited by

S.V.A.R. Sastry, Shravan Kumar,
Zeenat Arif and Amit Arora

Cambridge
Scholars
Publishing



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This book first published 2026

Cambridge Scholars Publishing

Lady Stephenson Library, Newcastle upon Tyne, NE6 2PA, UK

British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

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ISBN: 978-1-0364-6668-8

ISBN (Ebook): 978-1-0364-6669-5

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CHAPTER 1

A CRITICAL INSIGHT OF CLIMATE CHANGE AND ENVIRONMENTAL SUSTAINABILITY

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Abstract

In the present decade, environmental pollution and climate change have become serious concerns owing to the emission of various greenhouse gases (GHGs). This emerging issue is addressed by the World Health Organization (WHO), which ultimately results in worsening air quality and increased human health hazards. Different indicators of climate change and air pollution include allergic rhinitis, chronic rhinosinusitis, and head and neck cancer. In addition, an approximate annual death count of 150,000 people has been estimated as a result of climate change. Climate change is mainly associated with the anthropogenic release of greenhouse gases (GHG) into the atmosphere due to various reasons such as the burning of fossil fuels and incineration processes. The presence of GHGs in the atmosphere causes the trapping of infrared radiation from the earth's surface, which finally leads to an increase in the temperature at the earth's surface. The primary GHGs are carbon dioxide (CO₂) and methane. The other major contributors to air pollution are various particulate matters of less than 10 µm (PM10) or 2.5 µm (PM2.5) sizes. The presence of such pollutants in the air causes cardiovascular- and respiratory-related mortality in humans. Therefore, in this short review, we discuss the different causes of climate change and their various associated challenges and adverse effects.

Keywords: Climate Change; Green House Gasses (GHG-s); Environmental Pollution; Health Hazards; Particulate Matters.

1 Introduction

In recent years, anthropogenic greenhouse gas emissions have become the major cause of climate change and global warming. Its far-reaching consequences create an imbalance in ecosystems and affect biodiversity (Guo et al., 2021, 124843). It also poses an indirect impact on economic stability worldwide (Ngo et al., 2020, 424–446). Concurrently, environmental sustainability means meeting the needs of the present without compromising the needs of future generations (Avotra and Nawaz, 2023, 138301). The three main aspects of environmental sustainability are socio-economic and environmental, which have gained critical importance as humanity confronts the limits of planetary boundaries (Asif et al., 2023, 106145). However, environmental sustainability is inextricably associated with climate change. This can be exemplified by the effects of a cascade of environmental problems, such as global warming, greenhouse gas emissions, sea-level rise, and biodiversity loss. (Nguyen and Drakou 2021, 126828). Owing to these adverse effects, natural resources are depleted over time, leading to a global energy crisis. These effects also degrade ecosystems and threaten environmental sustainability (Chen et al., 2023, 165). Therefore, the problem of scarcity of essential services, such as clean water and fertile soil, puts the existence of stable climates at stake. Hence, to achieve environmental sustainability, we must consider human health hazards and environmental productivity. Therefore, immediate measures must be taken to mitigate the negative impacts of climate change (Ma et al., 2021, 125123). One way of doing this is to shift towards a low-carbon, resilient global society by reducing the carbon footprint in the atmosphere (Sui et al., 2024, 140216). This study aims to provide critical insights into the intricate nexus between climate change and environmental sustainability by evaluating various environmental impacts and the associated ways to solve them to achieve a sustainable future.

2 The Aspects of Climate Change

Various aspects of climate change mainly encompass the long-term shifts in global or regional climate patterns like global temperature rise (Hansen et al., 2025, 6-44). The main cause of the temperature increase may be attributed to rapid industrial growth and urbanization. For these two reasons, a significant amount of several greenhouse gases, such as carbon dioxide, methane, and nitrous oxide, and particulate matter are released into the atmosphere, causing global warming. Another potential reason for increasing concentration of these greenhouse gases is burning of fossil

fuels and deforestation (Banerjee et al., 2021, 575-583). Deforestation leads to increased pollution, soil erosion, and ecosystem imbalance. In addition to these effects, ocean acidification, sea-level rise, and more frequent and intense extreme weather events contribute to climate change. Some of these aspects are discussed in detail below.

2.1 Global Warming due to Greenhouse Gas Emissions

Global warming has emerged as an escalating crisis in modern times. The major greenhouse gases that contribute to global warming are CO₂, CH₄, and N₂O, etc. (He et al., 2024, 2668). The emission of these gases occurs due to vehicular and industrial emissions. The burning of fossil fuels for energy generation also releases vast quantities of greenhouse gases into the atmosphere. In addition, industrial processes release carbon dioxide, methane, and nitrous oxide, which act like a blanket, trapping heat and preventing it from escaping into space. As a result, the manifestation of intense heat waves may occur, which has the capability of altering stable environmental patterns and leads to the melting of glaciers and polar ice caps. The long-term effects of global warming include degraded human health and a poor economy, necessitating the reduction of emissions and the transition to sustainable energy sources (Rocque et al., 2021, e046333).

2.2 Impacts of Climate Change

The impacts of climate change may manifest in various interconnected ways. Some such examples may include degradation of human health and agricultural yields due to global temperature rise (Burke et al., 2015, 235-239). It also leads to glacial melt and rising sea levels, which endanger coastal communities through increased flooding and erosion. Apart from these, natural calamities like hurricanes, droughts, and wildfires are also caused by climate change, which leads to disrupted ecosystems and biodiversity loss (Jha and Tripathi 2023, 4273-4284). Hence the cumulative effect of these impacts disrupts the pillars of sustainability, such as environmental, social, and economic (Tol 2018, 4-25).

3 Environmental Sustainability and its Associated Challenges

3.1 Definition of Environmental Sustainability

Environmental sustainability can be defined as the “development that meets the needs of the present without compromising the ability of future generations to meet their own needs,” as per the Brundtland Commission's seminal 1987 report (Kates et al., 2005, 8-21). It is a broader concept that includes environmental, economic, and social aspects (Gerasimova 2017, 98). The environmental aspect refers to the responsible use and protection of natural resources and ecosystems (Robinson 2004, 379-384). This also ensures that consumption and production do not deplete or degrade natural resources, such as water and soil, so that future generations can meet their own essential needs.

3.2 Aspects of Boundaries of Environmental Sustainability

As stated above, the concept of environmental sustainability is primarily about the well-being of present and future generations by maintaining the Earth's natural and essential resources for future generations. In this context, three key aspects help us understand the boundaries and limitations of environmental sustainability (Algunaibet et al., 2019). Planetary Boundaries refers to a scientific framework proposed by Johan Rockström and a team of international scientists that identifies nine critical Earth system processes responsible for the stability and resilience of the planet (Rockström et al. 2009, 472-475). The main aim of these boundaries is to ensure “safe operating space for humanity.” Hence, crossing these boundaries leads to abrupt climate change and biodiversity loss (Steffen et al. 2015, 1259855). Conversely, humanity's demand on nature is being estimated through the ecological footprint. The main aim of the ecological footprint is to measure the requirement of productive land and sea areas to meet the needs of a given population and to absorb the waste it generates through sustainable resource-management practices. In this concept, it was observed that the ecological footprint can be compared to regenerating resources and absorbing waste. This concept also highlights the ecological overshoot due to the overconsumption pattern of a given population (Rees 2023, 509-527). Another important aspect is the carrying capacity, which refers to the maximum population size of a biological species that can be sustained indefinitely in a given environment. This concept is intricately linked to the consumption of

essential resources, such as food, water, and habitat, and the environment's ability to assimilate waste. Hence, overconsumption leads to resource depletion and environmental degradation (Ali & Audi, 2021, 251-260). Therefore, it can be said that these three concepts are interconnected, as planetary boundaries set the ultimate global limits for human activity, whereas the ecological footprint provides a way to measure our current demand against the Earth's capacity.

3.3 Threats of Environmental Sustainability

The major threats to environmental sustainability include biodiversity loss, ecosystem degradation, resource depletion, and environmental pollution. The adverse effects also include global temperature rise owing to the emission of greenhouse gases from vehicles and industries, extreme weather events such as droughts, heatwaves, floods, etc., rising sea levels owing to the melting of ice caps and glaciers, and ocean acidification (Jin et al., 2022, 11830). Soil erosion may also be caused by deforestation and habitat destruction. Species extinction may occur due to habitat destruction. Hence, the interaction between climate change and environmental sustainability creates a complex web of amplified risks, leading to more severe consequences. For example, rising global temperatures result in prolonged droughts, which are further intensified by freshwater scarcity. Similarly, it may also result in wildfires and the creation of a hotter climate, which accelerates biodiversity loss (Boegelsack et al., 2018, 461-467). In terrestrial environments, it may lead to sea-level rise and the salinization of freshwater. Therefore, it can be said that the “risk multiplier” magnifies vulnerabilities and necessitates integrated and holistic approaches to environmental management and adaptation.

4 Climate Change and Sustainable Development Goals (SDGs)

There is a close interplay between climate change and Sustainable Development Goals (SDGs), as it poses a serious threat to humankind (Lorenzo-Saez et al., 2021, 108246). The primary aim of the 17 SDGs is to end poverty, protect the planet, and ensure peace and prosperity for all by 2030. Among all 17 SDGs, climate change directly impacts SDG 13, which concerns climate action (Alnafrah et al., 2023). However, the adverse effects of climate change reverberate across nearly all other goals, including those related to poverty eradication (SDG 1), food security

(SDG 2), health (SDG 3), water and sanitation (SDG 6), and economic growth (SDG 8). Therefore, the focus has shifted towards achieving many SDGs, which promote the use of renewable energy, such as SDG 7, and sustainable cities, such as SDG 11. They offer potential pathways for mitigating the adverse effects of climate change on the environment. Therefore, an integrated approach is pivotal for enabling holistic sustainable development.

5 Strategies to Mitigate Climate Change

Several strategies have been implemented to mitigate the challenges of climate change. These are discussed as follows.

5.1 Reduction of Carbon Footprint into the Environment

Carbon emissions in the environment can be reduced by using renewable energy sources such as solar, wind, hydro, and geothermal energy instead of fossil fuels to avoid unnecessary pollution (Jia et al., 2024, 104751). Transitioning to these renewable energy sources also enables a paradigm shift towards a cleaner future with various promising aspects, such as energy storage and conservation, and a better circular economy. There are many ways available for carbon capture, utilization, and storage (CCUS), such as direct and indirect capture methods and chemical treatment methods. (Acampora and Grilletta 2025, 1883). All these methods contribute significantly to the reduction of carbon emissions into the biotic environment.

5.2 Practice of Sustainable Land Use and Forestry

One of the major approaches to sustainable land use is through afforestation, reforestation, and preventing deforestation. These practices also help to prevent soil erosion, especially in coastal areas (Alemu 2016, 502-506). In addition, sustainable agricultural practices may contribute to sustainable development. Recently, sustainable agricultural practices have been carried out through the adaptation of drone technology in sustainable farming to detect problem areas.

5.3 Sustainable Waste Management

Proper management of generated waste is a crucial aspect of sustainable practice. Waste management can be achieved through the 3Rs principle: reduce, reuse, and recycle (Yalçintaş et al., 2023, 1414). Sometimes,

valuable products are generated through the incineration of municipal solid waste, although it has the drawback of producing toxic gaseous byproducts. However, waste reduction and recycling enhance the circular economy and improve industrial processes.

5.4 Adaptation of Climate Change Strategies

To mitigate the effects of climate change, certain strategies such as green buildings, developing early warning systems for extreme weather conditions, water resource management in drought-prone areas, and sustainable and smart farming have been adopted (Etana et al., 2023). These measures are adopted to reduce vulnerability and enhance the resilience of both natural and human systems. In addition, sustainable land management practices and ecosystem restoration provide natural buffers against climate impacts. However, some bottlenecks still exist in the local context and in terms of stakeholder engagement. Therefore, the dissemination of proper knowledge is required to spread public awareness, which must go hand-in-hand with global efforts to reduce greenhouse gas emissions.

6 Framework of Policies and Governance for Sustainability

To achieve sustainability across environmental, social, and economic dimensions, a robust framework of policies and governance must be implemented. Policies include proper guidelines and regulations, as well as various incentives and standards (Zeijl-Rozema et al., 2007). These standards include emission limits, renewable energy subsidies, and sustainable land use. On the other hand, governance tells us about the ways of encompassing the intricate processes, institutions, and interactions among stakeholders like governments, civil society, the private sector, etc. Therefore, the basic job of governance is to monitor the development and implementation of these policies. This necessitates strong leadership, transparent decision-making, stakeholder engagement, and continuous learning and adaptation. Coordination across various levels and sectors also plays a pivotal role in this process. Instead of all such opportunities, there are some interconnected challenges, such as climate change and depletion of natural resources, to meet the growing energy demand. Hence, this integrated approach embeds sustainability into the core operations and strategic planning of organizations and society. Some of these aspects are discussed in detail.

6.1 International Agreements and Protocols

International agreements and protocols play a crucial role in achieving sustainability through collective recognition. In this context, the Paris Agreement is a landmark legally binding international treaty on climate change adopted by 195 parties in 2015. The main aim of this agreement is to limit the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit it to 1.5°C (Sanwal 2016, 1650008). To achieve this, countries must submit Nationally Determined Contributions (NDCs) outlining their climate action plans. Apart from the Paris Agreement, other vital protocols include the Montreal Protocol, the Convention on Biological Diversity, and the Basel Convention, which protect the ozone layer, conserve biodiversity, and control hazardous waste movements, respectively. Another vital international treaty is the Kyoto Protocol, which was adopted in Kyoto, Japan, on December 11, 1997, and entered into force on February 16, 2005 (Breidenich et al., 1998, 315-331). It discusses reducing greenhouse gas (GHG) emissions and operationalizes the United Nations Framework Convention on Climate Change (UNFCCC) by committing industrialized countries.

6.2 National and Sub-national Policies

To address climate change, national and sub-national policies are often used that talk about various aspects like carbon pricing through carbon taxes and cap-and-trade systems. (Basseches et al., 2022, 32). It directly discusses emissions reductions through carbon pricing. In contrast, cap-and-trade systems provide emission reduction targets by limiting the total amount of permissible emissions and allowing companies to trade allowances. In both sectors, innovation and investment in cleaner technologies, such as renewable energy, are implemented to achieve a sustainable future. In this context, several mandates, such as Renewable Portfolio Standards (RPS), give a brief approximation of the percentage of their electricity from renewable sources (Davies 2014, 3-75). Hence, the deployment of renewable energy technologies has become easier. In contrast, carbon pricing leverages economic signals, and mandates provide regulatory certainty.

6.3 Green Finance and Investment

One of the key factors to achieving global sustainability is to implement green finance and investment through proper channeling of financial

resources (López and López 2025, 332-362). It can overcome the challenges imposed by overlooking the environmental and social impacts of the traditional financing process. Hence, useful investment decisions can be made by investing in renewable energy projects and upgrading the efficiency of systems such as sustainable agriculture, biodiversity conservation, and pollution control (Zhou et al., 2023, 138873). Its main principle is to mobilize capital from the public, private, and not-for-profit sectors to make a paradigm shift towards a low-carbon, climate-resilient, and resource-efficient economy by mitigating climate change impacts.

7 Technological Innovations

In recent times, various technological innovations have been adopted to make significant shifts towards sustainable energy sources like solar, hydrothermal, geothermal, wind power, etc. In addition to these, advancements in smart grid technologies also make a significant shift towards a sustainable future (Baloch et al., 2022, 2290-2299). Due to the adoption of these technologies, a substantial reduction in our reliance on fossil fuels and overall carbon footprint happens. Besides, smart agricultural practices and the use of electric vehicles also help to reduce the carbon emissions in the atmosphere (Kautish et al., 2024, 120250). Therefore, by adopting these technological leaps, not only is production efficiency enhanced, but it also encourages circular economy principles that prioritize reuse and recycling of generated wastes for minimizing environmental impacts. In addition to the above, true sustainability hinges on a fundamental shift in human behavior that encourages adopting more environmentally conscious lifestyles (Dzhunushalieva and Teuber 2024, 100472). It's not just only about changing the individual mindset, but in a broader sense it involves a deeper transformation in values, attitudes, and consumption patterns. Hence, the main cornerstone of this process is effective public engagement and fostering a sense of ownership over sustainability initiatives.

8 Associated Challenges in Achieving Sustainable Future

Several critical challenges arise while navigating towards a sustainable future. The most common of these challenges is the accelerating pace of technological disruption due to skeptical mentalities and absence of proper knowledge among common people (Kumar et al., 2025, 263-270). Social unrest may also arise due to geopolitical instability and economic disparities.

8.1 Funding Gaps and Associated Barriers

In the scenario of economic disparities, funding gaps are one of the major bottlenecks, as they pose significant hurdles to achieving sustainability goals. Instead of public awareness, a persistent deficit and skepticism from the stakeholders in engaging financial resources often cripple ambitious sustainability initiatives (Barua 2019, 277-293). This mainly happens due to insufficient public funding and limited private sector investment. Hence, to resolve this kind of problem, multi-stakeholder collaboration is needed (Raman et al. 2025, 1513204). But still some issues persist due to difficulties in coordination between authorities and conflicting priorities of the stakeholders. These interwoven financial and operational impediments need to be addressed to achieve a sustainable future.

9 Probable Solutions

The associated challenges necessitate continuous adaptation of skill sets and organizational structures. Innovative solutions for sustainable development are very much required to mitigate the adverse effects of climate change through implementing green technologies and smart manufacturing processes (Yan et al., 2023, 122507). Proper management of resources at the industry level also scales up the process efficiency. In order to overcome geopolitical instability, diplomatic efforts and inclusive policies should be adopted (Varyvoda et al., 2023, 1-4). Integration of smart technologies like artificial intelligence and machine learning to promote the smart manufacturing process also helps to bring a sustainable future.

10 Climate Justice for sustainability

In order to achieve sustainability, climate justice needs to be done at a greater level, as it impacts social communities and nations due to global emissions (Roberts and Parks 2009, 385-409). There are some communities that are not responsible for a greater amount of emissions but still bear the heaviest burdens of extreme weather events and resource scarcity. So making climate justice means rectifying these ongoing injustices by advocating for a fair distribution of the responsibilities and benefits of the climate actions (Schlosberg, D., & Collins 2014, 359-374). This can be achieved by giving equal access to resources to all the people of a given community for adaptation and mitigation. This can be done by supporting their transition to achieve a low-carbon economy, without which proper justice towards sustainability can't be made (Newell et al. 2021, 733).

Hence, at the end, it perpetuates the very injustices that climate change exacerbates, ultimately undermining the collective well-being of present and future generations.

11 Conclusion

Environmental sustainability has been threatened to a serious extent because of issues of climate change. In this review study, the scientific consensus on anthropogenic climate change has been highlighted. The associated impact of climate change has also been addressed by exploring the pervasive impacts of changed climatic conditions. It also discusses the interrelation of climate change with environmental sustainability and how it is related to several sustainable development goals (SDGs). The essential strategies for mitigating emissions are also discussed in detail. In this context, the role of using renewable energy sources instead of using fossil fuels has also been emphasized, which helps to reduce the carbon emission into the environment. Hence, environmental sustainability requires a paradigm shift towards a regenerative and low-carbon equitable global society.

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CHAPTER 2

ANN METHODOLOGY FOR REMOVAL OF COPPER (II) FROM WASTEWATER USING BORASUS FLABELLIFER COIR POWDER

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The effective usage of adsorbent for the extraction of copper (II) was studied in a batch process from wastewater wherein influence of different adsorption parameters like the concentration of copper (II) (20-100 mg/L), the adsorbent dosage (10-14 g/L) and pH (5-9) on removal of copper (II) were examined using both ANN coupled with Genetic Algorithm. The adsorption parameters for the adsorption of copper (II) from wastewater of 20 mg/L have been predicted at optimum conditions using ANN models as follows. pH (6.1186 in ANN), adsorbent dosage (12.8486 g/L in ANN) and initial concentration of copper (II) (20 mg/L in ANN), Regression coefficient values (0.969 in ANN) and maximum percentage removal of copper (II) (96.0982% in ANN). In the development of ANN model using a feed forward architecture with back propagation, tansigmoid activation function in the hidden layer as input and purelin function for output layers, 41 experimental values for training and 13 data points for testing respectively were used to get minimum mean squared error (MSE) as well

optimum 14 neurons. The ANN model has been used successively and effectively for the extraction of Cu (II) from wastewater.

Keywords: Genetic Algorithm. Artificial Neural Network, Cu (II) removal and Adsorption.

1 Introduction

The contamination of industrial wastewater having heavy metals is environmental problem across the world. Heavy metals can be considered as toxic metals due to their bioaccumulation nature and non-biodegradability tendency in a biotic organism. Its level beyond threshold limits leads to severe causes on plants, animal's, marine life, plants and homosapiens [1]. Numerous heavy metals, including lead, mercury, manganese, copper, arsenic, and cadmium are well known as toxic metals because of their oxidation nature [2-3]. These heavy metals are being discharged into water bodies through different anthropogenic activities like volcanic activities and weathering of rocks, which are primary concern about pollution [4-5]. Among the said metals, Cu (II) is well known as toxic elements.

Source of copper in several industries include refineries, wood preservatives, metal cleaning, electroplating industries, paper and pulp, painting and fertilizer etc. The effluent having copper metal ion beyond limit may cause hepatic damage and renal, the nose irritation, gastrointestinal irritation, capillary damage, dizziness, stomach-aches, headaches, vomiting, diarrhoea and necrotic changes in liver and kidney. WHO has suggested that maximum threshold value for concentration of copper (II) metal in potable water must be 1.5 mg/l [6]. As result, the drinking water having heavy metals must be treated at lower cost.

A number of techniques like reduction [7], reduction followed by chemical precipitation [8], electrochemical precipitation [9], evaporation [10], foam separation [11], extraction technique [12], ion exchange [13] and novel membrane separation [14], above said copper elimination conventional techniques are ineffective and costly at lower concentrations. In the direction of reducing the cost, biosorption is given attention on using readily available raw and agricultural by products as bio-adsorbents for the metals extraction from water. It was investigated as low cost method for treating polluted water in effective manner whereby water quality may be enhanced.

The conventional mathematical techniques have failed for modeling and simulation of biosorption because of its having complex and nonlinear behavior and also interaction of more number of parameters [15]. A Good modeling and simulation tool need to be explored for obtaining the optimum management for any process control and also getting the process input parameters at optimum conditions [16]. In view of optimizing process parameters, one of the important techniques in the design of experiments is Artificial Neural Network [17].

Artificial Neural Networks (ANN) was applied for highly non-linear and complex adsorption process. The conventional models fail to simulate the mechanism of adsorption process i.e. particularly in environmental modelling [18]. The architecture of ANN and training algorithm was obtained by means of trial and error method to provide better solution for any complex problem with in allowable limits of error [19]. The pattern search algorithm with the Genetic Algorithm (GA) was operated through a population surviving fitter solutions by which conveying their traits to next population data which replace the poorer solutions [20]. The same population was opted to get the budding chromosomes. The selection depends on the fitness of individual solutions by deterministic sampling and roulette selection [21]. The ANN having GA algorithm coupled with RSM and particle swarm optimization (PSO) techniques were applied for heavy metals removal such as Cu (II), selenium (IV), Hg and Cd from water using nano-composites [22-25].

In the study, batch mode study [26] was performed for the removal of Cu (II) ion from wastewater by borasus flabellifer coir powder. The batch data was evaluated to get architecture of ANN with 14 neurons at optimum conditions. ANN the models were evaluated for verification of the batch data points that were not utilized previously for the adsorption parameters (adsorbent dosage, initial copper metal ion concentration and pH) for maximum removal of copper metal ion in the process optimization.

2 Summary of Experimental investigations

Scanning electron microscope of Fig.1 and Fig. 2 indicates that the surface of the adsorbent is porous, organic nature and also irregular. Hence it helps the sorption of Cu (II) ions on the active sites of borasus flabellifer coir powder.

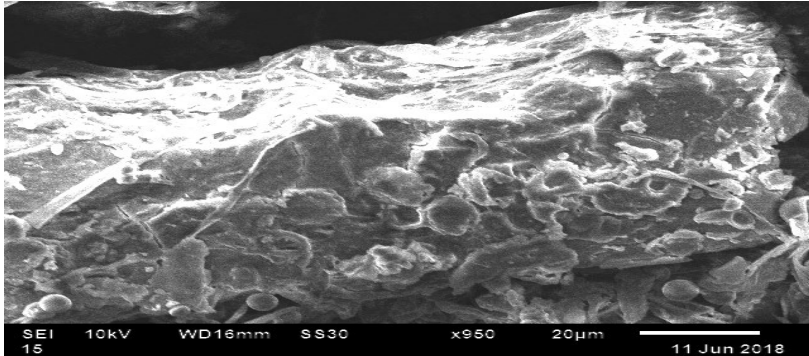


Fig. 2-1 SEM diagram before sorption of copper metal ion

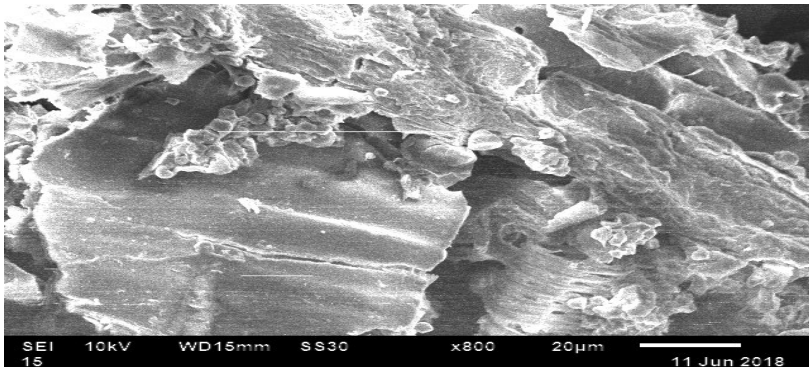


Fig. 2-2 SEM diagram after sorption of copper metal ion.

The measured weigh of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ was placed in pure water within 1 liter marked flask, meticulously filled to the specified value. This procedure yields a stock solution having 1000 ppm of copper (II). To generate synthetic solution with various concentrations of Cu (II), appropriate dilutions are carried out using this stock solution as the basis.

The adsorbents used were borasus flabellifer coir powder as an adsorbent. The borasus flabellifer coir collected from a local market underwent a series of processing steps. Initially, they were thoroughly washed followed by drying. The roll crusher and hammer mills were used to grind the feed after proper drying. The crushed material was subjected to screening using BSS meshes. The products after screening were stored within silos, ready for the subsequent investigation focused on the extraction of heavy metals.

The Cu (II) removal from water was examined through batch studies. These investigations aimed to assess the impact of several parameters on the process. The parameters studied included adsorbent size at 63 μ m-125 μ m, dosage of adsorbent (0.2-0.7 g in 50mL solution), time for agitation (0 -120 min), adsorbate concentration (20-100 mg/L) and pH (2-10). These investigations were conducted under 200 revolutions per min in a shaker at known time.

3 Results and Discussions

3.1 ANN model

ANN model optimized structure has been shown in Fig. 3. It features a multilayer level feed forward architecture with one hidden layer having sigmoid transfer function, and a linear transfer function in the output node, applied across all data sets. The back propagation algorithm was followed for ANN training. ANN model data was obtained using MATLAB software

ANN model was developed by considering three input variables: The adsorbent dosage (ranging from 10 to 14 g/L), pH (ranging from 5 to 9) and concentration of copper (II) (ranging from 20 to 100 mg/L)) and percentage extraction of copper (II) as output variable. The total 54 data points (41 and 13 points for training and testing) have been used in ANN model.

The building of topology in an ANN model involves choosing the appropriate set of using input variables, output variables, number of layers, nature of transfer functions and the number of nodes in each layer. The next task is optimizing the ANN topology. The number of neurons was evaluated based on minimizing mean squared error (MSE). In view of evaluation of the optimum number of neurons, various topologies have been tested with number of nodes ranging from 2 to 23. For testing the accuracy of neural network, each topology was evaluated 3 times. The MSE indicates the performance of the network.

The minimum MSE for modelling of a single layer level feed forward back propagation neural network was achieved with 14 nodes in the hidden layer (according to Fig. 4). Table 1 indicates the weights and bias values for ANN model. The ANN network has been tested by comparing its model results with experimental results using leftover data points. Fig. 5 shows the plot of experimental values versus the predicted values. It indicates that the points are nearly clustered around a linear line. Based on regression coefficient R^2 value of 0.969, Fig. 5 indicates that both the experimental and predicted values are aligned closely and also about

robustness of the model. Table 2 presents a comparison between predicted copper (II) extraction by ANN model and experimental values.

The result indicates that the predicted values from ANN model and experimental removal efficiency values are nearly equal, with minimal relative error. Based on overall ANN model prediction data, present model developed by ANN is simple, good efficiency and satisfactorily tool for the extraction of Cu (II). Hence ANN proves to be an attractive option for handling complex systems.

Optimization of adsorption parameters for Cu (II) removal was performed using ANN coupled with genetic algorithm. The optimized adsorption parameters are detailed as below

1. The adsorbent dosage-12.8486 g/L
2. The copper (II) concentration-20 mg/L
3. pH-6.1186

96.0982 of the highest percentage Cu (II) removal and 1.8351 of residual sum of squares have been obtained at optimum adsorption parameters.

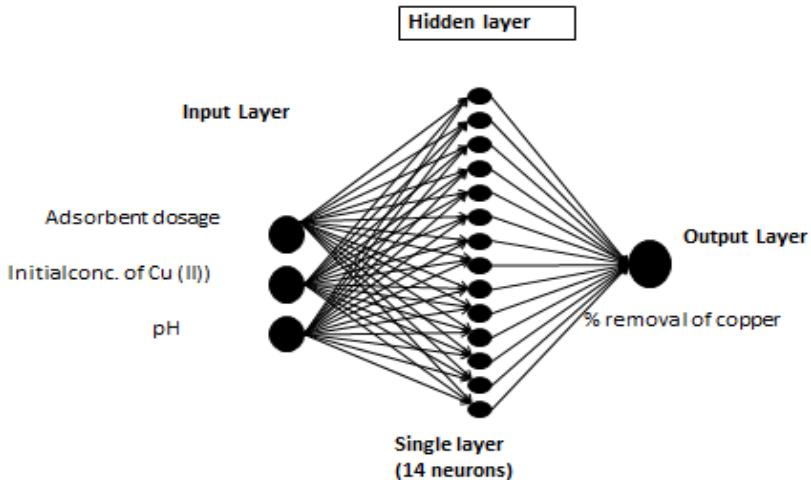


Fig. 2-3 Optimized ANN architecture