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▪ Carbon Material Synthesis	▪ Biomass Valorization

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  "**Thesis Title:** Removal of Phosphorus from Wastewater using Nano-calcium Hydroxide and Aragonite Synthesized by Hydration or Carbonation of Waste Seashells".
- 2016 Master of Science in Chemical Engineering, University of Nottingham, Nottingham, UK, 2015-16. [70.27% (4.0/4.0 GPA), Distinction].
- 2015 Bachelor of Technology in Chemical Engineering, Aligarh Muslim University, Aligarh, India, 2011-15. [78.9% (9.0/10.0 CPI), Distinction].
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Research Experience

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- 2017 Employed for 6 months as a Project Assistant in CSIR-Indian Institute of Petroleum, Dehradun, India. Worked on biomass valorization and activated carbon synthesis.

Published Papers

- **Khan, M.D.**; Shakya, S.; Vu, H.H.T.; Habte, L.; Ahn, J.W. Low concentrated phosphorus sorption in aqueous medium on aragonite synthesized by carbonation of seashells: Optimization, kinetics, and mechanism study. *J. Environ. Manag.* 280, 2021, 111652.
- **Khan, M.D**.; Chottitisupawong, T.; Vu, H.H.T.; Ahn, J.W.; Kim, G.M. Removal of phosphorus in aqueous solution by nano-calcium hydroxide derived from waste bivalve seashell: Mechanistic insights. *ACS Omega* 5, 2020, 12290-12301.
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- Vu, H.H.T.; **Khan, M.D.**; Chilakala, R.; Lai, T.Q.; Thenepalli, T.; Ahn J. W.; Kim, J. Utilization of lime mud waste from paper mills for efficient phosphorus removal. *Sustainability* 11 (6), 2019, 1524.
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- **Khan, M.D.**; Ahn, J.W. Ion Exchange Processes: A potential approach for the removal of natural organic matter from water. *J. Energy Engg.* 27 (2), 2018, 70-80.
- **Khan, M.D.**; Lee, S.; Ahn, J.W. Consequences and remediation of climate change with focus on clean water and sanitation in India. *J. Energy Engg.* 27, 2018, 65-75.

Book Chapter

- **Khan, M.D.**; Ahn, J.W. Chapter titled “Environmental benign biochar technologies: Strategic utilization for CO_2 capture and wastewater treatment”, Ed. Jyothi, R.K., in book “Clean Coal Technologies”, to be published by Springer Nature in February 2021.

University Level Academic Projects

- 2016 (Research Paper) Comparison of Properties and Texture of Activated Jatropha Residue with Activated Hydro Char of Jatropha Residue. [University of Nottingham, Nottingham, UK].
- 2016 Techno-economic feasible design of Hydrogen Production Plant from Shale gas. [University of Nottingham, Nottingham, UK].
- 2016 Techno-economic feasible design of Hydrothermal Carbonization Plant with Wheat Residue as feed. [University of Nottingham, Nottingham, UK].
- 2015 Techno-economic feasible design of Dimethyl Carbonate Production Plant from Methanol & Lime. [Aligarh Muslim University, Aligarh, India].

Awards and Achievements

- 2019 Won UST Overseas Training Program and offered sponsorship by University of Science and Technology to do research training in University of Queensland, Australia.
- 2017 Awarded full scholarship (~ 1500 USD) by the University of Science and Technology for the whole duration of PhD i.e. 2017 – 2021.
- 2016 Awarded 1st Prize for student design project judged to achieve highest standard in design practice. [University of Nottingham, Nottingham, UK].
- 2015 Awarded Merit Scholarship by Indian Institute of Chemical Engineers (NRC).
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- 2014 Awarded University Merit Financial Award
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Conferences Attended

- Presented on topic "Effective Phosphorus Removal from Aqueous Medium by Nanoparticles Prepared from Waste Mussel Shells" in **"The 15th International Symposium on East Asian Resources Recycling Technology, EARTH 2019"**, 2019, Pyeongchang, Republic of Korea.
- Presented on topic "Arsenic and Fluoride contaminated groundwaters: Consequences and Remediation Techniques" in **"45th International Association of Hydrogeologists"**, 2018, Daejeon, Republic of Korea.
- Presented on topic "The Impact of Nano Titanium Electrode on Electrochemical Reduction of Nitrate in Ground Water" in the **"The 16th KOREA/JAPAN International Symposium"**, 2018, Seoul, Republic of Korea
- Participated in the National workshop on **"Advances in Bio-process Engineering and Technology"**,2014, Department of Chemical Engineering, Aligarh Muslim University, Aligarh, India.
- Participated in the national Symposium on **"Nanotechnology for Chemical Applications"**, 2013, Department of Chemical Engineering, Aligarh Muslim University, Aligarh, India.

Extracurricular Activities

- Secretary, Society of Aligarh Chemical Engineering Student (SAChES), for session 2014-15.
- Secretary of Organizing committee of workshop on "Disaster Management", 2014, Department of Chemical Engineering, Aligarh Muslim University, Aligarh, India.
- Member of organizing committee of workshop on "Solid Waste Management", Department of Chemical Engineering, Aligarh Muslim University, Aligarh, India.
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- References available onrequest.

ARTICLE IN PRESS

Journal of Environmental Management xxx (xxxx) xxx

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: http://www.elsevier.com/locate/jenvman

Research article

Low concentrated phosphorus sorption in aqueous medium on aragonite synthesized by carbonation of seashells: Optimization, kinetics, and mechanism study

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A R T I C L E I N F O

Keywords:
Phosphorus
Bivalve seashell
Adsorption
Aragonite
Wastewater

A B S T R A C T

Phosphorus (P) concentration beyond threshold limit can trigger eutrophication in stagnant water bodies nevertheless it is an indispensable macronutrient for aquatic life. Even in low P concentration ($\leq$1 mg L^{-1}), P can be detrimental for ecosystem's health, but this aspect has not been thoroughly investigated. The elimination of low P content is rather expensive or complex. Therefore, a unique and sustainable approach has been proposed in which valorized bivalve seashells can be used for the removal of low P content. Initially, acicular shaped aragonite particles ($\sim$21 μm) with an aspect ratio of around 21 have been synthesized through the wet carbonation process and used to treat aqueous solutions containing P in low concentration ($P \leq 1$ mg L^{-1}). Response surface methodology based Box-Behnken design has been employed for optimization study which revealed that with aragonite dosage (140 mg), equilibrium pH ($\sim$10.15), and temperature (45 °C), a phosphorus removal efficiency of $\sim$97% can be obtained in 10 h. The kinetics and isotherm studies have also been carried out (within the range $P \leq 1$ mg L^{-1}) to investigate a probable removal mechanism. Also, aragonite demonstrates higher selectivity (>70%) towards phosphate with coexisting anions such as nitrate, chloride, sulfate, and carbonate. Through experimental data, elemental mapping, and molecular dynamic simulation, it has been observed that the removal mechanism involved a combination of electrostatic adsorption of Ca^{2+} ions on aragonite surface and chemical interaction between the calcium and phosphate ions. The present work demonstrates a sustainable and propitious potential of seashell derived aragonite for the removal of low P content in aqueous solution along with its unconventional mechanistic approach.

1. Introduction

Phosphorus (P) in the form of phosphates (H_2PO^{4-}, HPO_4^{2-}, and PO_4^{3-}) holds numerous industrial applications such as in fertilizers, detergents, and food industries (Awual, 2019; Mor et al., 2016). The discharge of generated wastes with excess P lead to severe environmental problems particularly to the water ecosystem, causing eutrophication with algal blooms and death of aquatic species due to lack of dissolved oxygen (Xie et al., 2017; Liu et al., 2012a). Therefore, efficient P decontamination with minimal impact on the environment becomes a global necessity. Researchers provided evidence that P as low as $\sim$0.02 mg L^{-1} can trigger an acceleration in eutrophication (Heathwaite and Sharpley, 1999). The United States Environmental Protection Agency (EPA) and European Union (EU) have recently endorsed stringent legislations comprising a threshold limit of $P < 0.05$ and 0.01 mg L^{-1} for each stream of treated water intersecting any natural reservoir (Loganathan et al., 2014). The Water Framework Directives also compressed the P permissible limit from 1 to 2 mg L^{-1} to 0.1 mg L^{-1} (Shepherd et al., 2016). The majority of the reported adsorbents were converged towards the adsorption of P in high concentration ($P > 20$–30 mg L^{-1}) in wastewater, whereas few reports were found focussing on adsorption of low P concentration ($P < 1$ mg L^{-1}). Indeed, P concentration in the most

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https://doi.org/10.1016/j.jenvman.2020.111652
Received 19 August 2020; Received in revised form 20 October 2020; Accepted 6 November 2020

ACS OMEGA

http://pubs.acs.org/journal/acsodf

Article

Removal of Phosphorus from an Aqueous Solution by Nanocalcium Hydroxide Derived from Waste Bivalve Seashells: Mechanism and Kinetics

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Cite This: *ACS Omega* 2020, 5, 12290−12301

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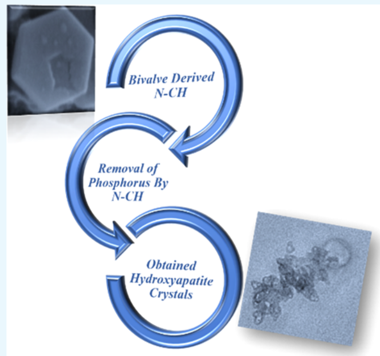
ABSTRACT: Excessive supply of phosphorus, a vital macronutrient for all organisms, can cause unwanted environmental consequences such as eutrophication. An increase in agricultural and industrial activities has created a considerable imbalance in the phosphorus cycle with continuing adverse effects on sustainability and ecosystem health, thereby stipulating/postulating the significance of phosphorus removal. A unique and sustainable concept for the removal of phosphorus through the utilization of waste bivalve seashells was proposed in the present study. Flat-surfaced and hexagonally shaped nanocalcium hydroxide particles (∼96% purity) with size ranging from 100 to 400 nm have been synthesized, and phosphorus from its aqueous solution is treated via precipitation. An optimization study has been conducted using the Box−Behnken design of response surface methodology, which highlights that with a calcium/phosphorus mass ratio, pH, and temperature of 2.16, 10.20, and 25.48 °C, a phosphorus removal efficiency of 99.33% can be achieved in a residence time of 10 min. Also, under the same conditions, diluted human urine was analyzed and phosphorus removal efficiency of ∼95% was observed. Through experimental results, semiquantitative phase analysis, and transmission electron microscopy, it has been found that the reaction was diffusion-controlled, which was further confirmed through shrinking core diffusion modeling. The present study manifests the promising potential of waste seashell-derived nanocalcium hydroxide for phosphorus treatment and its precipitation in the form of value-added hydroxyapatite.



■ INTRODUCTION

Phosphorus (P) is referred to as a limiting nutrient in the context of water degradation through eutrophication. Excess P concentration can trigger abnormal growth of aquatic plants, particularly, algae.[1] Many researchers have provided evidence highlighting the acceleration of eutrophication when P concentration exceeds 0.02 mg L^{-1}.[2] The United States Environmental Protection Agency endorses a total P concentration of <0.05 mg L^{-1} for each stream entering any natural reservoir.[3] The European Union has more stringent legislation and recommends threshold limits for P concentration as <0.01 mg L^{-1} (nonrisk) and >0.1 mg L^{-1} (risk condition) in lakes and other natural reservoirs.[3] According to the Water Framework Directive, the permissible limit for P concentration has been reduced to 0.1 mg L^{-1}, which was earlier set to 1−2 mg L^{-1}.[4] Various chemical, biological, and physical approaches have been developed for effective P removal, such as chemical precipitation, ion exchange, electrochemical adsorption, membrane filtration, and crystallization.[5−8] Most of these methods possess some limitations, such as high cost, complex operation, low purity, and secondary wastes, while crystallization is mainly referred to as an economically viable method exhibiting a considerable recovery rate, helping in production of valuable products and minimization of environmental risks.[8,9]

Recently, the use of wastes, such as steel slag,[9] calcite,[10] eggshell,[11] red mud,[12] seashells,[13,14] and lime mud,[15] for P removal has been actively attempted, since these materials have low cost and wide availability. Bivalves are one such group of waste available in abundance and are generally dumped either in open fields or in landfills.[16] The Food and Agriculture Organization (2016) reported that Europe, Japan, South Korea, and Thailand are among the leading producers of bivalves with the estimated quantity of 632 000, 377 000, 347 000, and 210 000 tonnes, respectively. Above all, China itself dumped annually more than 10 million tonnes of bivalve waste in landfills.[16,17] It has been reported in previous studies that the adverse effects of bivalves, such as evolution of hazardous gases, including ammonia, amines, and hydrogen sulfide, and health issues, like malaria, diarrhea, and cholera, could occur when dumped in public waters and open fields.[14] Being rich in calcium, these bivalve wastes can be valorized into desired calcium products, which can be utilized in the

Received: March 5, 2020
Accepted: April 14, 2020
Published: May 21, 2020

Journal of Environmental Management 223 (2018) 947–951

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Short communication

Environmental benign synthesis, characterization and mechanism studies of green calcium hydroxide nano-plates derived from waste oyster shells

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ARTICLE INFO

Keywords:
Calcium hydroxide
Nano-plates
Waste oyster shell
Aqueous medium
Eco-friendly

ABSTRACT

Continuous dumping of oyster shells in open fields has been a global issue, causing serious problems in the water and human health. The conversion of those wastes into value-added products is highly desirable. Here, Green Calcium Hydroxide Nano-plates (GCHNPs) were first synthesized from waste oyster shells by a chemical precipitation method in an aqueous medium at 90 °C without using any additives. The crystal structure with a hexagonal portlandite ($Ca(OH)_2$) was observed by both X-ray diffraction (XRD) and Fourier transform infrared spectroscopy (FT-IR). The crystal size of around 350–450 nm and specific surface area with 4.96 m^2g^{-1} were confirmed by field emission scanning electron microscopy (FE-SEM) and Brunauer-Emmett-Teller (BET), respectively. In addition, a schematically organized new qualitative model for a mechanism was proposed to explain the genesis and evolution of GCHNPs from raw oyster shells.

1. Introduction

Solid waste management is one of the major barriers for a sustainable world. Varieties of solid waste recycling using the plastic, glass, waste tires, e-waste, paper waste etc. are in limelight nowadays (Godlewska, 2017; Kumar et al., 2017; Mohajerani et al., 2017; Pivnenko et al., 2015; Ragaert et al., 2017). Due to ever increasing human population some food wastes are becoming threats to our environment. An oyster shell, one such waste available in abundance, accounting for almost 1/3 of total bivalve's production, has been a global issue (Lu et al., 2018). According to FAO (2016), Europe produced 632,000 tonnes of bivalves in 2014. In South East Asia on an annual average basis, Japan, South Korea and Thailand produced 377,000, 347,000, and 210,000 tonnes of bivalves respectively. China being the leading producer of bivalves disposed annually about 10 million tonnes of waste sea shells in landfills (Yao et al., 2014). According to Li et al. (2015), problems arise when the shells are considered as wastes which account for about 60–70% of their original weight after utilization of these food. Severe environmental issues arise when those wastes are dumped in open dumps and public waters. As an example, the microbial decomposition of flesh remnants causes health issues such as diarrhea, malaria and dengue. In addition, hazardous gases including hydrogen sulphide, ammonia and amines are generated (Felipe-Sese et al., 2011; Varhen et al., 2017; Yoon et al., 2003). Aforementioned wastes are responsible for huge deposits of which only minor portion is being utilized with purposes such as calcium supplements, fertilizers and handicrafts (Lu et al., 2018; Yang et al., 2005). Even though those wastes can be used as fertilizers and handicrafts, recycling or reuse for waste oyster shells has a few drawbacks. Pretreatment processes should be required to remove the organic impurities. In addition, a calcination process is mandatory to use the raw oyster shells where the process requires high energy consumption. Therefore, a conversion of those wastes into a product with high economic value is highly desirable.

Nowadays nanotechnology dominates in the field of science and technology. Numerous consequences have been reported by Pandey and Prajapati (2018) with conventional nanoparticles like Fe, Cu, Zn, Pt etc. Since those nanoparticles are not eco-friendly, the dose above the threshold limit can damage the cellular physiology by the generation of reactive nitrogen and oxygen species. In addition, it has been extensively reported that the deposition of nanoparticles in organs like brain and heart causes cytotoxic effects on macrophages, which ultimately affect the human immune system (Sahu et al., 2014; Wang et al., 2010). Recently, the trend in nanotechnology is shifting towards eco-friendly nano-materials (Hajipour et al., 2012; Mane et al., 2017; Roy et al., 2017). Among a variety of eco-friendly nano-materials, calcium hydroxide ($Ca(OH)_2$) being an eco-friendly compound, has been utilized in a variety of environmental, chemical and industrial applications

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https://doi.org/10.1016/j.jenvman.2018.07.011
Received 2 May 2018; Received in revised form 24 June 2018; Accepted 5 July 2018
0301-4797/

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Communication

Water Environment Policy and Climate Change: A Comparative Study of India and South Korea

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Received: 30 April 2019; Accepted: 11 June 2019; Published: 14 June 2019

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Abstract: Climate change is considered to be a potential cause of global warming, which leads to a continuous rise in the global atmospheric temperature. This rising temperature also alters precipitation conditions and patterns, thereby causing frequent occurrences of extreme calamity, particularly droughts and floods. Much evidence has been documented by the Intergovernmental Panel on Climate Change, illustrating fluctuations in precipitation patterns caused by global climate change. Recent studies have also highlighted the adverse impact of climate change on river flow, groundwater recovery, and flora and fauna. The theoretical political approach and scientific progress have generated ample opportunities to employ previously allusive methods against impacts caused by varying climatic parameters. In this study, the current state of India's water environment policy is compared with that of South Korea. The "3Is"—ideas, institutions, and interests—which are considered pillars in the international field of political science, are used as variables. The concept of "ideas" highlights the degree of awareness regarding climate change while formulating water environment policy. Here, the awareness of India's management regarding emerging water issues related to climate change are discussed and compared with that of South Korea. The concept of "institutions" illustrates the key differences in water environment policy under the umbrella of climate change between both countries within the associated national administrations. India's administrations, such as the Ministry of Environment, Forests, and Climate Change; the Ministry of Water Resources, River Development, and Ganga Rejuvenation; the Ministry of Rural Development; and the Ministry of Housing and Urban Affairs, are used as a case study in this work. Finally, the concept of "interest" elaborates the prioritization of key issues in the respective water environment policies. Common interests and voids in the policies of both countries are also briefly discussed. A comparison of India's water environment policies with that of South Korea is made to expose the gaps in India's policies with respect to climate change, thereby seeking to identify a solution and the optimal direction for the future of the water environment policy of India.

Keywords: climate change; sustainability; environment; water policy; India; South Korea; precipitation

1. Introduction

The Sustainable Development Goals (SDGs) were consensually adopted in September 2015 by the United Nation member states during the 2030 Agenda for Sustainable Development. These SDGs are

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Communication

Synthesis, Characterization and Mechanism Study of Green Aragonite Crystals from Waste Biomaterials as Calcium Supplement

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Received: 22 May 2020; Accepted: 19 June 2020; Published: 22 June 2020

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Abstract: In present work, environmentally benign green aragonite crystals were synthesized from waste chicken eggshells and bivalve seashells through a simple and low-cost wet carbonation method. This method involves a constant stirring of calcium oxide slurry and magnesium chloride suspension in aqueous solution with constraint carbon dioxide injection at 80 °C. The physicochemical properties of the synthesized aragonite were further compared with the aragonite synthesized from commercial calcium oxide. The morphological analysis, such as acicular shape and optimum aspect ratio (~21), were confirmed by scanning electron microscopy. The average crystal size (10–30 µm) and specific surface area (2–18 m^2 g^{-1}) were determined by particle size and Brunauer–Emmett–Teller analysis, respectively. Moreover, a schematic crystal growth mechanism was proposed to demonstrate the genesis and progression of aragonite crystal. Green aragonite can bridge the void for numerous applications and holds the potential for the commercial-scale synthesis with eggshells and bivalve seashells as low-cost precursors.

Keywords: aragonite; carbonation; bivalve seashell; eggshell; precipitation

1. Introduction

Precipitated calcium carbonate (PCC) has emerged as a potential inorganic material with numerous industrial applications, particularly as filler in polymers, paints, and paper [1,2]. Among three available polymorphic forms of PCC (i.e., calcite, aragonite, and vaterite), under ambient conditions, calcite is thermodynamically most stable while vaterite can be considered unstable [2]. Aragonite being metastable has been extensively reviewed considering its biocompatible and superior mechanical properties. Aragonite (2.93 g cm^{-3}) is more compact and denser than calcite (2.71 g cm^{-3}), thereby can provide better tensile strength, yield strength, and yield strain when used as filler [3]. Other applications include water treatment [4], replacement and additive to bone [5], and biomedical activities [6]. Synthesis of acicular shaped aragonite is evident in many studies [1,2,7,8]. A study reported that

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Review

Aggravation of Human Diseases and Climate Change Nexus

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Received: 17 July 2019; Accepted: 1 August 2019; Published: 6 August 2019

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Abstract: For decades, researchers have debated whether climate change has an adverse impact on diseases, especially infectious diseases. They have identified a strong relationship between climate variables and vector's growth, mortality rate, reproduction, and spatiotemporal distribution. Epidemiological data further indicates the emergence and re-emergence of infectious diseases post every single extreme weather event. Based on studies conducted mostly between 1990-2018, three aspects that resemble the impact of climate change impact on diseases are: (a) emergence and re-emergence of vector-borne diseases, (b) impact of extreme weather events, and (c) social upliftment with education and adaptation. This review mainly examines and discusses the impact of climate change based on scientific evidences in published literature. Humans are highly vulnerable to diseases and other post-catastrophic effects of extreme events, as evidenced in literature. It is high time that human beings understand the adverse impacts of climate change and take proper and sustainable control measures. There is also the important requirement for allocation of effective technologies, maintenance of healthy lifestyles, and public education.

Keywords: climate change; infectious diseases; pathogens; vectors; human adaptation

1. Introduction

Climate change is a significant statistical shift in regional or global climate variables over a considerable period of time (decades or even more). The most sensitive climatic variables include precipitation pattern, humidity, average and peak temperatures, and wind [1]. Although the global mean temperature and other climatic variables were relatively stable for millennia, recent decades have witnessed considerable changes [2]. The European Environment Agency reported a rise of 0.74 °C in global mean temperature in the 20th century, a continuous 1.8 mm per year expansion of sea level since 1961, and a 2.7% reduction in Arctic sea ice per decade [3]. Climate experts have also confirmed the dramatic increase in the frequency and severity of extreme weather events over the last few decades. Moreover, a remarkable rise of 1.5 °C to 5.8 °C in global mean temperature was predicted by the Intergovernmental Panel on Climate Change (IPCC) in the 21st century, accompanied by more severe weather events dominated by floods and droughts [4,5]. Climatologists have also provided very clear evidence that even a short-term climatic variation can pose serious threat to human health in many different ways.

Climatic variations can significantly influence human health through the emergence of various infectious diseases [6–9]. Pathogens, vectors, and favorable transmission conditions are the three essential components involved in most infectious diseases [7]. Optimum climatic conditions are a prerequisite for reproduction, survival, mortality, and spatiotemporal distribution of vectors and