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Biomimetic materials and technologies for carbon neutral cities in South Africa: a literature review

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Abstract

The accelerating decline in the environment and increasing atmospheric concentration of greenhouse gases (GHGs) are closely linked to human activities. This has caused the menace of climate change with the impact globally felt. The continent of Africa, given its geographical location, is believed to be more vulnerable and will severely feel these impacts. To curtail this, mitigation and adaptation have been recognised as the most potent strategies to curtail the challenge of climate change. Increased adaptive capabilities of infrastructures and systems in South Africa is, therefore, imperative. This paper explores biomimicry, a new field that studies and emulates the forms, processes, and strategies found in natural organisms to solve human challenges. For its over 3.8 billion years of evolution, nature has effectively and efficiently tackled many of the challenges mankind is grappling with today. Hence, the objective of this study is to evaluate and present existing biomimetic materials and technologies which contribute less to the degradation of the environment. Biomimetic materials and technologies, known to possess sustainable credentials will reduce the release of GHGs and has the potential for carbon sequestration. The result will help offer sustainable alternatives to those materials and products which significantly contribute to the increase in carbon footprint.

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Keywords: biomimicry; construction industry; CO2 emission; greenhouse gas; nature

1. Introduction

The role the construction industry plays in the overall improvement of the quality of life of the society is salient and significant [1]. It is also noteworthy that globally, investing heavily in the industry is used to stabilise the economy thereby confirming the industry's leading status in the national development masterplan of many nations

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[2]. This is evident through the provision of infrastructural facilities which have in turn profited humanity as well as improved the economic development of many countries [3]. It is also proven that the sprawl in urbanisation is proximately connected to the industry due to its associated buildout [4]. The provision of cogent infrastructures such as roads, rail, bridges, waste, and waste water treatment plants, energy production and transmission plants, residential, commercial and industrial facilities [5] amongst many others are examples of buildouts linked with the construction industry.

However, in the process of urbanisation and economic development globally, the construction industry has been identified as a major player in environmental degradation and pollution. Attesting to this fact is the replacement of vegetation and forests with impermeable concrete surfaces of buildings and roads [6]. Infrastructures are known to have a long-term effect on the human environment due to their continuous emission of pollutants in large quantities [7]. Based on a study by the United States Environmental Protection Agency (USEPA), indoor pollutant levels are often higher than those outdoor, usually 2.5 and occasionally 100 times higher [5]. The study also reveals that most people spend as much as ninety percent (90%) of their time indoors [5] making them susceptible to the risks associated with the pollutants. Indoor pollutants are those emanating from backing materials, paints and other components in the building. However, a report by the United Nations Environment Programme – Sustainable Buildings & Climate Initiative (UNEP-SBCI), undertaken in collaboration with the Construction Industry Development Board (cidb) identified the construction industry to be a major contributor to CO_2 emissions in South Africa [8]. Sustainable activities, materials, and technologies should, therefore, be adopted by the construction industry in reducing its negative environmental impacts globally. The objective of this paper, therefore, is to examine biomimetic technologies and materials with low or zero environmental impact in other to achieve carbon neutral cities in South Africa.

2. Carbon emission in the construction industry

The construction industry is branded as the major emitter of atmospheric pollutants of which carbon dioxide (CO_2) is a constituent. These pollutants, CO_2 and other non- CO_2 greenhouse gasses (halocarbons, chlorofluorocarbons, and hydrochlorofluorocarbons) significantly contribute to the depletion of the ozone layer resulting in climate change. CO_2 emissions associated with building energy use in China reaches 1260 million tons in 2008 [9] while fifty percent (50%) of carbon emissions in the United Kingdom is traceable to the industry [10]. A critical examination revealed that processes, materials production and use, and other associated activities in the construction industry, are the sources through which the atmospheric concentration of carbon and other pollutants is greatly increased. South Africa, amongst other African nations, are greatly hit by the consequences of CO_2 emissions despite contributing minimally. In 2008, two-third of the global CO_2 emissions are generated by ten nations while China and the USA alone generate about forty-one percent (41%) of world CO_2 emissions [11].

Most notably is the production of cement which contribute significantly to the amount of GHG emissions through fossil fuel combustion, breakdown of raw materials involved in its production and electricity consumption [12,13]. Concrete, been the most widely used material in the construction industry [14], has cement as one of its key constituent [15] and serving as a binding component. It is, however, noteworthy that, in the production of $1m^3$ of concrete alone, several activities are involved which in turn contribute to the release of CO_2 emissions into the atmosphere. This is shown in Fig 1. below. In other to reduce the atmospheric concentration of CO_2 as a result of the production and use of concrete, Carbon Capture and Storage (CCS) emerged as a new technology designed to capture and squash CO_2 emissions into a liquid state for permanent underground storage [16]. Alternative cement with less or zero environmental impact has also been advocated as against the widely used Ordinary Portland Cement [14].