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Exploring the Interplay of Air Pollution, CO_2 Emission, Energy Consumption, and Health Risks in Nanotechnology Applications

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Abstract

This research examines the interconnections between nanotechnology and its impact on airpollution, carbon dioxide (CO_2) emission, energy consumption, and potential health risks associated with nanomaterials and nanotechnology applications. The study investigates the complex relationship between these factors, with a focus on understanding their implications for sustainability and human heatlth. Furthermore, the integration of nanomaterials in renewable energy technologies, including biomass, solar, wind, hydropower, and geothermal energy, offers opportunities for improving energy efficiency, reducing CO_2 emissions, and overall energy consumption. However, it is crucial to address the potential health risks associated with nanomaterials. The unique properties of nanomaterials can pose challenges to human health, including respiratory effects, skin and eye irritation, toxicity concerns, and long-term unknown effects. In this study, will apply the unit root test, Johansen co-integration test, VECM, and Granger Causality Test for secondary data to examine the correlation between the variables. In conclusion, this review highlights the importance of sustainable practices in nanotechnology. It emphasizes the need to strike a balance between the benefits of nanotechnology and considerations for environmental impact, energy efficiency, and human health. Collaboration among researchers, policymakers, and industry stakeholders is crucial for establishing effective guidelines, regulations, and standards to promote the safe and sustainable growth of nanotechnology.

Keywords

Nanotechnology, Air pollution, Carbon dioxide emission, Energy consumption, Renewable energy

Introduction

Air pollution

The issue of air pollution is a worldwide environmental concern that presents substantial risks to both human health and the ecosystem [1]. Simultaneously, nanotechnology has arisen as a promising discipline that can tackle diverse environmental challenges, such as air pollution. Nevertheless, it is imperative to analyze the ramifications of air pollution on nanotechnology, as contaminants in the atmosphere can significantly affect the characteristics and efficacy of nanomaterials. Comprehending this interaction is of utmost importance in the prudent advancement and efficient execution of nanotechnology-driven approaches for addressing air pollution [1-3].

The presence of air pollutants, including reactive gases and particulate matter, can induce changes in nanomaterials' stability, structure, and properties through their interaction. The interactions mentioned above have the potential to influence the efficacy and durability of nanomaterials utilized in environmental applications. Moreover, it is worth noting that airborne nanoparticles, which are released through combustion processes, industrial operations, and vehicle discharges, have the potential to interact with engineered nanoparticles. This interaction can alter the engineered nanoparticles' behavior, aggregation, and toxicity [4].

Figure 1 shows nanomaterials application in air pollution remediation [5]. Air pollution can lead to the contamination of nanomaterials on surfaces. The accumulation of atmospheric pollutants onto the surfaces of nanomaterials can give rise to a coating of impurities that has the potential to influence their performance and chemical reactivity. Contamination can potentially impact the efficacy of nanomaterials in various environmental remediation or sensing applications. One of nanotechnology's most beneficial environmental applications is the remediationof air pollution. This involves the utilization of various nanomaterials, such as nanoadsorbents, nanocatalysts, nanofilters, and nanosensors. Nanomaterials possess the capacity to adsorb various airborne contaminants [5, 6].

Figure 1: Nanomaterials application in air pollution remediation.

Furthermore, it is important to consider the potential health effects associated with air pollution, particularly the presence of nanoparticles in the air. Nanotechnology offers tools for air quality monitoring, enabling the sensitive detection of pollutants in real-time. However, the release of nanoparticles from nanotechnology-based solutions for air pollution mitigation raises concerns about their potential risks to human health [1, 7]. Air pollution, including fine particulate matter (PM2.5) and toxic gases, can have adverse health effects on human beings. When considering nanotechnology-based solutions for air pollution mitigation, it is essential to assess the potential risksassociated with the release of nanoparticles and ensure their safety.

Despite these challenges, nanotechnology can contribute to addressing air pollution by offering innovative solutions. Nanocatalysts for pollutant degradation, nanofilters for air purification,and nanostructured materials for pollutant capture are among the potential applications of nanotechnology in air pollution remediation. However, understanding the impact of air pollution on these nanomaterials is essential for assessing their long-term efficacy and environmental implications [6].

Moreover, the interaction between air pollution and nanotechnology extends to the broader context of climate change. Nanotechnology can play a role in climate change mitigation through the development of energy-efficient materials, carbon capture technologies, and sustainable energy generation [8]. However, it is necessary to evaluate the impact of air pollution on the performance and stability of nanomaterials involved in these climate change solutions. These models provide a framework for evaluating the performance, efficiency, and sustainability of nanotechnology-based solutions for air pollution control in Malaysia. Figure 2 refer to the Malaysian nanotechnology-based air pollution control technologies' performance, efficiency, and sustainability.

The investigation of the influence of air pollution on nanotechnology is a crucial factor to contemplate in the advancement and implementation of nanotechnology-driven remedies for the alleviation of air pollution. Through a comprehensive comprehension of the interplay between air pollutants and nanomaterials, researchers can enhance nanotechnology's configuration, performance, and safety to effectively tackle air pollution issues while simultaneously mitigating potential hazards to human well-being and the ecosystem.

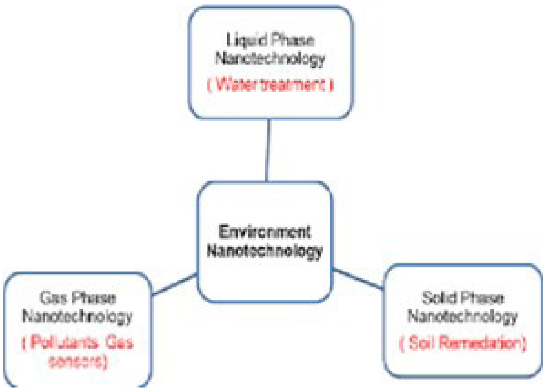


Figure 2: Malaysian nanotechnology-based air pollution control technologies' performance, efficiency, and sustainability.

Carbon emission

The production of nanomaterials involves energy-intensive processes, leading to the release of carbon dioxide and other greenhouse gases. These emissions contribute to climate change and environmental degradation. Nanotechnology itself can play a crucial role in mitigating CO_2 emissions [9]. Nanotechnology plays a significant role in supporting carbon capture and storage endeavors by developing sophisticated materials characterized by enhanced surface areas and customized properties, thereby enabling more effective capture and sequestration of CO_2. Because of increased CO_2 emissions in Earth's atmosphere and the melting of polar ice caps, which raises sealevels and causes climate shifts, global warming occurs. Additionally, fossil fuel use in many sectors,such as the home and the industrial sector, is a significant contributor to the rising CO_2 emissions. According to the International Energy Agency [10], coal and industrial processes accounted for 65 percent of all CO_2 emissions in 2018, which is concerning since it puts the whole planet in danger. Energy consumption, for example, fuels in vehicles, emit CO_2 as waste when burnt. This is rampant mainly in developing countries because most motors used in developing countries are already used in developed countries.

Dangerous levels of CO_2 emissions have thrown the international community into a tantrum due to the rising environmental decay. In Malaysia, most of the carbon emission originates from theconsumption of fossil fuels used to power most transport machines and industries motor mobiles, for example, coal which is a key source of energy. These are directly linked to development and significant economic growth. In contrast, they play an important role in economic growth through energy utilization.

According to World Data Atlas [11] Malaysia's CO_2 emissions in 2020 were 262.2 million tons. CO_2 emissions in Malaysia have increased dramatically during the previous 50 years, risingfrom 14.7 to 262.2 million tons, and rising. This annual gain peaked at 19.93 percent in 1991 beforedropping to -0.95 percent in 2020. The inter-governmental panel on climate change [12] cited that CO_2 emission is the main contributor to greenhouse gases. This report showed that 76.7%of greenhouse gases contributed to CO_2 emitted by developing countries like Malaysia.

Energy Consumption in Malaysia

Energy is critical to Malaysia's economic development, and any disruption in energy supply would have a significant negative influence on the country's economic progress. Malaysia's energy demand is estimated to reach 116 million tons by 2020, representing an annual growth rate of 8.1 percent. As a result, Malaysia will require additional resources to fund its rapid economic expansion. Fossil fuels continue to be Malaysia's primary source of electricity, count for over 94.5 percent of the country's total electricity production [13].

Nanomaterials and nanotechnology applications offer innovative solutions for improving energy efficiency and developing carbon capture and storage technologies. By incorporating nanomaterials into various industries, such as catalysis and energy storage, energy consumption can be reduced, thus indirectly reducing CO_2 emissions [4, 14]. Figure 3 refers to the percentage of total final energy consumption [15].

A change of trend has occurred in Malaysia renewable energy consumption since the year 2010. The graph above shows a change in Malaysia percentage of renewable energy consumption from the year 1990 - 2018. Malaysian energy consumption plunged into the use of non-renewable energy from the tears of 1990 to 2007, showing an increased drop in the consumption of renewable sources. Policies and different approaches with the aim of reducing carbon emissions due to the use of harmful non-renewable sources are enacted every year but seemingly showed results from 2010. The country aims to be a carbon-neutral country by 2050, said ex-prime minister Datuk Seri Ismael Sabri Yaakob [16]. Figure 4 refer to the Key Source of Greenhouse Gas Emissions – Percentage Share for Malaysia, 2011 [17, 18].

The pie chart (Figure 4) depicts Malaysia's percentage share of global greenhouse gas emissions in 2011 and various subsections of Malaysia's carbon emissions sources in 2011. It shows that energyconstitutes the largest portion of greenhouse gas emissions. Our government focuses more on petroleum which is non-renewable energy. That is why the greenhouse emission is mostly from that energy. This report is from UNFCC 2015 [17].

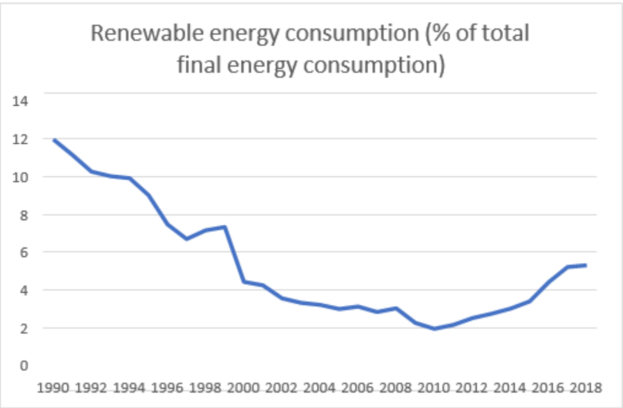
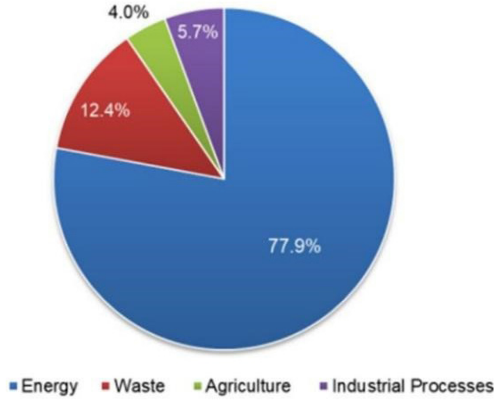


Figure 3: Percentage of total final energy consumption.



Source: Malaysia Biennial Update Report to the UNFCCC 2015,
Ministry Of Natural Resources and Environment Malaysia

Figure 4: Key source of greenhouse gas emissions – percentage share (%) for Malaysia, 2011.

Impact of Nanomaterials on Various Renewable Energy Technologies

Nanomaterials have the potential to have a substantial influence on the reduction of energy consumption across diverse renewable energy technologies. Nanomaterials have the potential to enhance the effectiveness and efficiency of various renewable energy sources, including biomass energy, solar energy, wind energy, hydropower energy, and geothermal energy.

Figure 5 refers to the renewable energy sources [19]. Nanotechnology can enhance the efficacy of biomass energy production and utilization. Using nanocatalysts has improved the efficiency and selectivity of chemical reactions in converting biomass feedstocks into biofuels, such as bioethanol and biodiesel. Nanomaterials have the potential to be employed in gasification procedures to generate syngas from biomass, which can subsequently be utilized to produce power. Nanomaterials have been found to play a significant role in

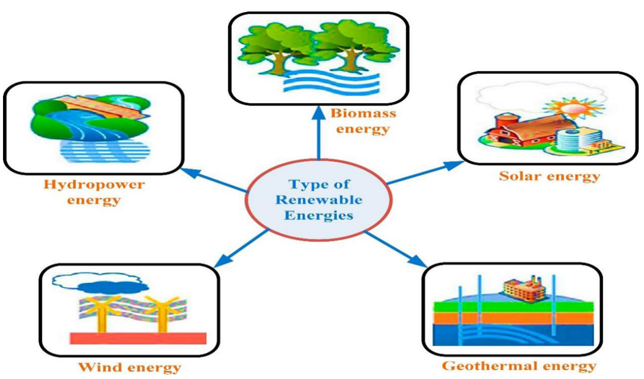


Figure 5: Renewable energy sources.

enhancing the efficiency of biomass conversion processes, resulting in decreased energy consumption and increased energy yields [19-21].

Moreover, nanomaterials are extensively utilized in solar energy applications, including photovoltaic and solar thermal systems. The utilization of nanoparticles, nanowires, and thin-film structures has significantly enhanced the processes of light absorption, charge transport, and energy conversion in solar cells. Utilizing nanomaterials in solar cells enables elevated power conversion efficiencies, diminishing the small amounts of solar energy necessary for generating electricity. Furthermore, nanomaterials enhance the performance of solar thermal collectors' heat transfer and absorption capabilities [19, 22, 23].

The utilization of nanomaterials has the potential to improve both the efficiency and durabilityof wind turbines significantly. Integrating carbon nanotubes or nanocomposite materials into wind turbine blades can enhance their mechanical strength and stiffness, thus facilitating the developmentof longer and lighter blades. Consequently, there is an enhancement in energy capture efficiency anda decrease in energy consumption during the turbine operation. Nanocoating's have been found to offer protective benefits for wind turbine surfaces. These benefits include mitigating the effects of corrosion and erosion, enhancing the overall lifespan of wind turbines, and reducing the need for frequent maintenance [19, 24].

Furthermore, the utilization of nanomaterials has the potential to improve the efficiency of hydropower generation systems significantly. An example of the potential benefits of nanoscale coatings is their ability to reduce the frictional forces between water and turbine blades, thereby enhancing the efficiency of converting water flow into mechanical energy. Nanosensors can monitorand enhance the water flow within hydropower systems, facilitating higher power generation efficiency. On top of that, the utilization of nanomaterials in water treatment procedures has proven to be effective in eliminating contaminants and preserving the operational effectiveness of hydropower plant infrastructure [19, 25].

Nanomaterials can enhance the efficiency of geothermal energy extraction and conversion. Nanofluids, consisting of nanoparticles dispersed in a heat transfer fluid, can improve the heat transfer properties in geothermal systems. These nanofluids increase thermal conductivity and convective heat transfer, enhancing the overall energy extraction efficiency. Nanomaterials can also be used to develop advanced materials for geothermal heat exchangers and energy storage systems, improving the overall efficiency and reducing energy consumption [19, 25-27].

In a nutshell, using nanomaterials holds substantial potential for mitigating energy consumption in diverse renewable energy applications, encompassing biomass, solar, wind, hydropower, and geothermal energy [25]. Nanotechnology plays an essential part in advancing renewable energy sources and achieving a more sustainable energy future through enhancing energy conversion efficiency, improving heat transfer properties, and optimizing system performance.

Potential Health Risks Associated with Nanomaterials and Nanotechnology Applications

Nanomaterials and nanotechnology applications have introduced exciting possibilities across various industries, but they also raise concerns regarding potential health risks. The unique properties of nanomaterials, such as their small size and increased reactivity, can pose challenges to human health. Inhalation of airborne nanoparticles is a primary concern, as they can penetrate deep into the respiratory system and potentially enter the bloodstream. This raises the risk of respiratory disorders,inflammation, and even systemic effects. Skin contact with certain nanomaterials may cause irritation, and, in some cases, lead to toxic effects. Additionally, the biocompatibility of nanomaterials remains a critical aspect, as they may exhibit unexpected toxicological responses at the cellular and molecular levels. The ability of nanoparticles to interact with biological molecules and penetrate cellular barriers raises concerns about unintended consequences and unknown long-term effects. Furthermore, the accumulation of nanomaterials in the environment and their potential to bioaccumulate in living organisms pose ecological and health risks. Occupational exposure is another significant concern, as workers involved in nanotechnology-related activities may face higher risks due to direct contact with nanomaterials. To address these health risks,it is crucial to conduct comprehensive toxicological studies, develop safety guidelines, and implement appropriate risk assessment protocols. By adoptingresponsible practices and ensuring proper safety measures, the potential health risks associated with nanomaterials and nanotechnology applications can be effectively managed, enabling their safe and sustainable integration into various industries [7, 28-33].

Smart Environment Monitoring System Using Technology

Collecting and analyzing data is what environmental monitoring is all about, so scientists can learn more about how the world works and how it impacts people. Rainfall and soil composition are two examples of natural data sources, whereas data on trash disposal and car emissions come from human and industrial activity [34]. Smart settings aim to improve people's daily lives by introducing features that make their surroundings safer, more convenient, and less taxing on the environment.

Smart cities,smart buildings, smart retail, and smart industries are all examples of "smart environments," which are specialized applications of the Internet of Things. Environmental monitoring, made possible by the Internet of Things, gives real-time insights into the state of the environment, allowing for educated decisions to be made in its defence. The necessity for efficient environmental monitoring has grown in significance as the relevance of combating climate change and other environmental concerns has grown [34].

Adopting the environment technology

Air, soil, and water are the primary targets of environmental monitoring in the natural world. To analyze air pollutants, for instance, sensor networks and GISs collect and analyze data on pollution, topography, and weather. Chemical, radiological, and biological data are measured against population size in water monitoring. To analyze soil quality for farming and to foresee the possibility of erosion, floods, and risks to environmental biodiversity, soil monitoring involves testing soil samples for salt, pollution, and acidity [35].

Proposed Research Methods

Secondary data is data gathered by the researcher from past studies as well as likely with other purposes [36]. Compared to primary data, researchers would be able to get secondary data in a far quicker and faster way. For this study, secondary data will be employed for independent variables such as technology and environment. Secondary data will be collected from the Ministry of Science, World Health Organization, World Bank and Technology and Innovation. This secondary data will be employed to investigate the determinacies of carbon emission and renewable energy consumption on nanotechnology in Malaysia. The model estimation for this is shown as below:

$$NNTt = f\ (RNEWt, CO_2t)$$

Where NNTt is the nanotechnology in Malaysia (dependent variable), while renewable energy consumption in Malaysia (RNEWt), and carbon emission of Malaysia (CO_2t) are the independent variables.

All variables are expressed in the natural logarithms and the logarithmic form of functional regressionmodel is written as follows:

$$LNNTt = \beta 0 + \beta 1RNEWt + \beta 2CO_2t + \mu$$

For this study, an Augmented Dickey-Fuller and Phillips-Perron unit root test will be used to test the stationary of NNT, RNEW and CO_2 variables. Furthermore, this paper will be using the Johansen and Juselius Multivariate cointegration test to investigate whether there is a long-run relationship between the dependent variable (LNNT) and independent variables (LRNEW) and (LCO_2) using trace and maximum eigenvalue statistics. VECM can be used if the variables are cointegrated. The data will be run using VECM to find the long-run correlation between variables. The next step is to proceed with the Granger Causality Test within VECM to examine the short-run causal relationship between independent and dependent variables.

Conclusion

In conclusion, this review has highlighted the interconnectedness of various factors in the context of nanotechnology. The impact of air pollution, CO_2 emission, and energy consumption on nanotechnology applications has been examined, revealing both challenges and opportunities. The findings underscore the importance of developing sustainable practices within the field of nanotechnology to mitigate environmental and health risks. By leveraging nanomaterials, it ispossible to enhance the efficiency of energy production, reduce CO_2 emissions, and improve overall energy consumption. However, it is crucial to acknowledge the potential health risks associated with nanomaterials and nanotechnology applications. The unique properties of nanomaterials can pose challenges to human health, including respiratory effects, skin and eye irritation, toxicity concerns, and unknown long-term effects. These risks must be carefully evaluated, and stringent safety measures should be implemented to ensure the responsible development and application of nanotechnology. Moving forward, it is recommended to focus on further research and development efforts that prioritize the integration of nanotechnology with sustainable practices. This includes continued exploration of nanomaterials that minimize environmental impacts, improve energy efficiency, and mitigate potential health risks. Developing comprehensive guidelines, regulations, and standards to facilitate nanotechnology's safe and sustainable expansion necessitates the crucial involvement of researchers, policymakers, and industry stakeholders in collaborative efforts. Nanotechnology has the potential to make substantial contributions towards advancing a more sustainable and environmentally aware society through its focus on addressing environmental challenges, optimizing energy consumption, and safeguarding human health. It is essential to balance the potential benefits with responsible practices, continuous monitoring, and a proactive approach towards addressing emerging challenges in the field of nanotechnology.

Acknowledgments

None

Conflict of Interest

None

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