CHAPTER ONE

INTRODUCTION

"The world is reaching the tipping point beyond which climate change may become irreversible. If this happens, we risk denying present and future generations the right to a healthy and sustainable planet – the whole of humanity stands to lose."

- *Kofi Annan, Former Secretary-General of UN*

Overview: This chapter introduces the research problem of our study, supported by relevant literature and data. Further, the objectives of the study are also outlined in this chapter.

1.1. Introduction:

Recent global warming and climate change concerns have highlighted the negative side of industrialization on the environment. Industrialization is inevitable for achieving economic growth. At the same time, it has been marked as one of the most influential factors that lead to environmental pollution. Industrial activities cause air, water, soil, noise and many other types of pollution in a country. Among all, the most harmful impact of industrialization is the escalation of carbon dioxide (CO_2) emission levels. Reliance on fossil fuel energies, chemical processing, waste disposal, deforestation, and so forth, are the industrial activities leading to significant environmental pollution (Fujii & Managi, 2016; Jing et al., 2020). It has become vital that the impact of industrial activities on the environment be strictly monitored from time to time and that sustainability practices are followed. The need of the hour is sustainable industrialization to help achieve environmental sustainability.

Sustainable industrialization is the key approach in today's era to maintain a balance between the economic necessity for industrial expansion and the obligation to protect the environment. It improves social well-being by incorporating cleaner technologies and practices (United Nations, 2014). In other words, it guides nations to achieve economic welfare over economic growth that meets present fiscal needs without compromising the ability of future generations to thrive. Particularly, developing countries have been facing serious dilemmas regarding the choice between industrial growth and environmental shelter

(Kumar. J & Majid, 2020; Sreenu, 2022). Prioritizing industrialization for economic growth is critical but ignoring its environmental consequences will not guarantee society's long-term well-being. Therefore, the balance between industrial growth and environmental harmony has become a matter of serious concern in modern times.

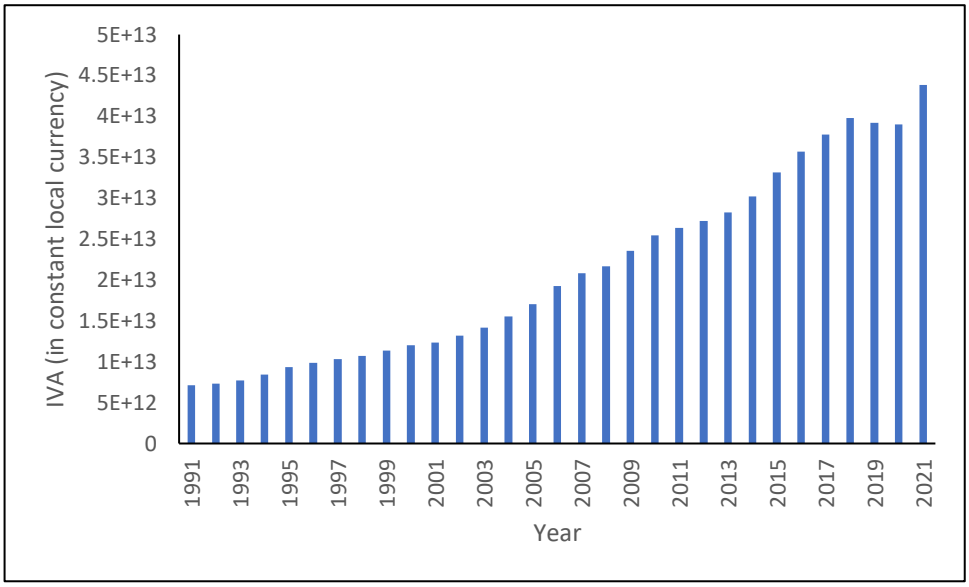
India is one of the fastest-growing economies, while at the same time, it is recognized as one of the most polluting nations globally. The country has witnessed drastic growth in the fields of industrialization in the last few decades. While on the one hand, it has helped achieve higher economic growth for India, on the other hand, this has several environmental challenges. Thus, economic growth has been achieved at the cost of environmental deterioration. The reliance on fossil fuel sources of energy is the major cause of carbon emissions and environmental degradation. Hence, balancing economic growth and carbon emissions is indispensable for achieving sustainable development.

The environmental Kuznets curve (EKC) hypothesis and decoupling analysis are two commonly used assessment methods for sustainable development (Lv et al., 2021). The EKC hypothesis describes the relationship between economic growth and environmental degradation. A traditional inverted U-shaped EKC implies that pollution increases at low levels of economic growth and decreases when higher economic growth is achieved (Grossman & Krueger, 1991; Kuznets, 1955). Likewise, a decoupling approach facilitates valuable insights into the level of environmental efficiency of the industries by assessing the relationship between industrial growth and its consequential level of CO_2 emissions.

1.2. Industrialization in India:

In the past few years, industrialization has shown remarkable growth in India. To achieve faster growth, the Indian economy has largely relied on its industries to increase production levels, generate funds and become self-reliant. Industrial growth is required to promote domestic production for import substitution and contribute towards the improvement of the overall living standards of the people. As shown in Figure 1.1, the industry value added has increased approximately by 518 percent from 1991 to 2021. The country has shown an average industrialization growth of 6.13 percent during this period.

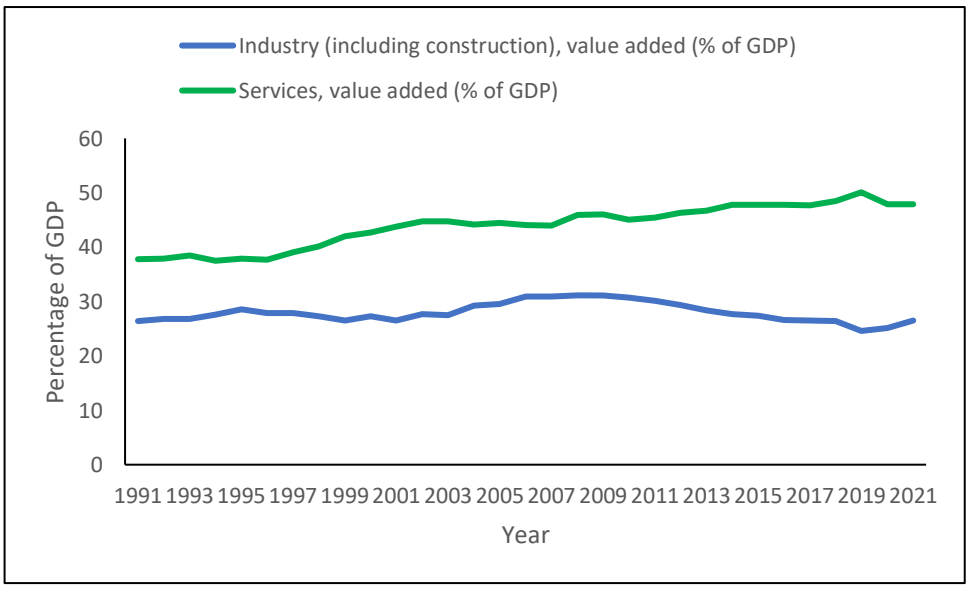
Figure 1.1: Industry value added in India



(Author's compilation; Source: World Bank)

Figure 1.2 shows the contribution of industry and service value added towards India's gross domestic production (GDP) from 1991 to 2021. During the period, it has contributed towards GDP in the range of 24 to 32 percent every year. This is comparatively lower than the value of the service added in the country, which has contributed in the range of 37 to 51 percent towards India's GDP from 1991 to 2021.

Figure 1.2: Share of industry and services value added in the GDP of India



(Author's compilation; Source: World Bank)

India's industrial revolution began in the mid-19th century under colonial rule, when the cotton and jute industry started flourishing in the country. During this period, modern

industrial infrastructure like railways and telegraphs were developed. By the early 20th century, heavy industries slowly entered India's market with the introduction of steel plants. Thereafter, cement, electrical equipment and chemical industries took forward the industrial revolution in the country. Overall, in the pre-independence period, India built a reputation in terms of textiles, handicrafts, metals, spices, metals, etc. industries and showed its true potential on the global market. After the colonial era, India tried to continue its industrial glory by introducing various policies and measures for the industries' further fostering.

Post-independence, the Indian government has been paying ample attention towards its industries to facilitate faster and more stable growth. In India, Industrial Policy resolutions have been announced post-independence as a government intervention to encourage domestic producers and influence the structure of industrialization in the country. As per the demand and requirements of the Indian economy, several adjustments have been made to the Industrial Policies from time to time. The Industrial Policy 1991 came into practice in India after several Industrial Policy Resolutions (1948, 1956) and Industrial Policy Statements (1973, 1977 and 1980) (Office of the Economic Adviser, 2009). From 1950 to 1980, the Industrial Policies were focused on supporting the growth of the small-scale and infant industries following an industrial protectionism policy. However, these policy frameworks could not show the desirable outcomes due to the highly competitive world markets. With time, the Industrial Policies started moving towards the prioritization of heavy industries for faster economic growth attainment post-1980 (Nayyar & Nayyar, 2024). The highlights of this journey are mentioned below:

Industrial Policy Resolution, 1948: Apart from being the first Industrial Policy Resolution, this resolution has a historic significance in Indian industrialization as it declared India's economy as a mixed economic structure. The resolution prioritized providing necessary support for the growth of the small-scale and cottage industries.

Industrial Policy Resolution, 1956: This industrial policy was prepared in line with the Second Five-Year Plan (1956–61), emphasizing industrialization, infrastructure development, and social welfare. Popularly known as the 'Economic Constitution of India', the resolution categorized the Indian industries into three Schedules based on their scope and traits. It continued to promote the cottage and small-scale industries to eradicate unemployment and rural poverty.

Industrial Policy Statement, 1973: It allowed investments from large industrial corporations and foreign companies in identified high-priority sectors of the economy. These industries were permitted to start operating in backward rural locations to ensure inclusive growth. Meanwhile, special legislation was introduced to protect the welfare of the cottage and small-scale industries. The primary highlight of the statement was the identification of the six core industries of the country, recognizing their salient role in achieving India's economic growth.

Industrial Policy Statement, 1977: It divided the small-scale and large-scale industries into different categories to cater to their specific needs and requirements for smooth growth operations. Special attention was provided to the cottage and small-scale industries for the overall development of the rural and town locations.

Industrial Policy Statement, 1980: The policy emphasized the role of technological advancement and modernization in domestic industries to promote exports. Limited foreign investments were allowed in selected industries after this policy statement.

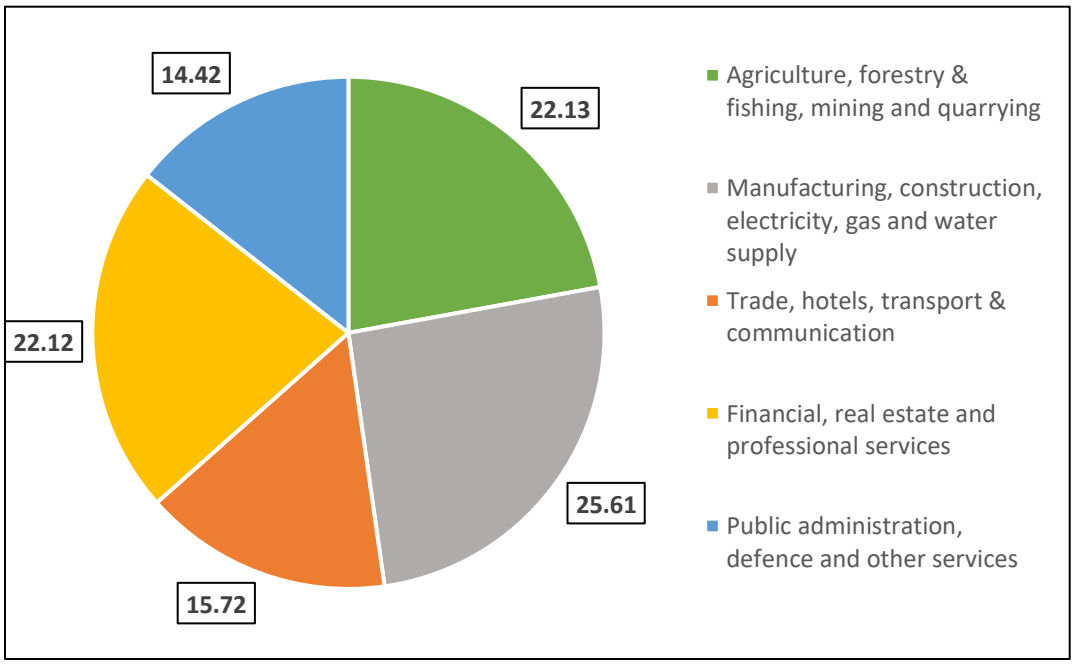
Industrial Policy, 1991: After the economic reforms in 1991, the Indian industries were nurtured for international standards. The policy is popular for taking drastic measures such as the abolishment of industrial licensing, allowing for foreign investments up to 51 percent in 33 selected industries, automatic approval for technology agreements with high-priority industries and strengthening public enterprises, etc. Through the LPG (Liberalization, privatization and globalization) framework, the economic doors of India were opened for foreign entrepreneurs to enter, believing that their presence would increase market competitiveness and positively influence the quality of the nation's domestic production.

The present industrialization structure in India is driven by efforts to achieve sustainability with a comprehensive approach by promoting technological advancements and structural reforms. The "Make in India" initiative of the Indian government in 2014 boosted local manufacturing, attracting both domestic and foreign investments. Recently in 2020, the government launched the "Aatmanirbhar Bharat Abhiyan" (Self-reliant India Movement) to encourage self-sustenance and self-generation of funds among its population, with an attempt to revive the roles of small-scale and cottage industries. The "Tribal Entrepreneurship Development Program" also began in 2020 to promote entrepreneurship as a means of becoming self-reliant among tribal groups of India in particular. However,

challenges continue to exist in the country, including infrastructural gaps, regulatory bottlenecks and the need for skill development to meet industrial demands. With the growing digitalization and the adoption of Industry 4.0, India's industrial setup is progressing to meet both domestic and global market demand, establishing itself as a valuable player in the global supply chain.

The sectoral composition of the Indian economy has changed over the years. The primary sector's contribution towards total output has decreased drastically from 51.3 percent in 1950-51 to 20.3 percent in 2019-20. In contrast, the secondary sector's role has increased from 14.5 percent in 1950-51 to 25 percent in 2019-20. The tertiary sector has achieved the biggest growth in the total output contribution from 34.2 percent in 1950-51 to 54.8 percent in 2019-20 (Nayyar & Nayyar, 2024). Figure 1.3 shows the sectoral composition of the Indian economy in the year 2020-21. Here, the industrial sector comprising the manufacturing, construction, electricity, gas and water supply contributed 25.61 percent to the total gross value added of the Indian economy.

Figure 1.3: Sectoral composition in gross value added in 2020-21



(Author's compilation; Source: Economic Survey 2023-24)

The Monopolies and Restrictive Trade Practices (MRTP) Act in 1969, the Competition Act in 2002, the Production Linked Incentives (PLI) Scheme in 2020, etc. are some of the

notable acts and schemes in India that contributed towards promoting a fairly competitive market and providing uniform opportunities for industries to achieve growth in the country.

As mentioned above, in the Industrial Policy Statement of 1973, the Indian government introduced a new category of industries which came to be known as the 'core industries'. Initially, there were six industries listed under this categorization for their outstanding contributions to the country's economic growth. These industries are coal, crude oil, cement, electricity, steel and refinery products industries. The core industries performed relatively better in terms of the Index of Industrial Production (IIP). IIP is an indicator representing the growth of India's various industrial sectors, published by the government of India every month. Later, the government started to separately publish another indicator to capture the growth of the Indian core industries, which is called the Index of Eight Core Industries (ICI). The first ICI series was released with the base year of 1980-81, considering the initial six core industries. Later, the base year was revised to 1993-94, 2004-05 and 2011-12. In the 2004-05 publication on ICI, two more industries namely the fertilizers and the natural gas industries, were included in the list of the core industries. In 2021, these eight core industries represented 40.27 percent of the IIP basket in India. In the coming years, the responsibility of the core industries is expected to grow even more in order to nurture faster economic growth in India.

1.3. Industrialization and Environment:

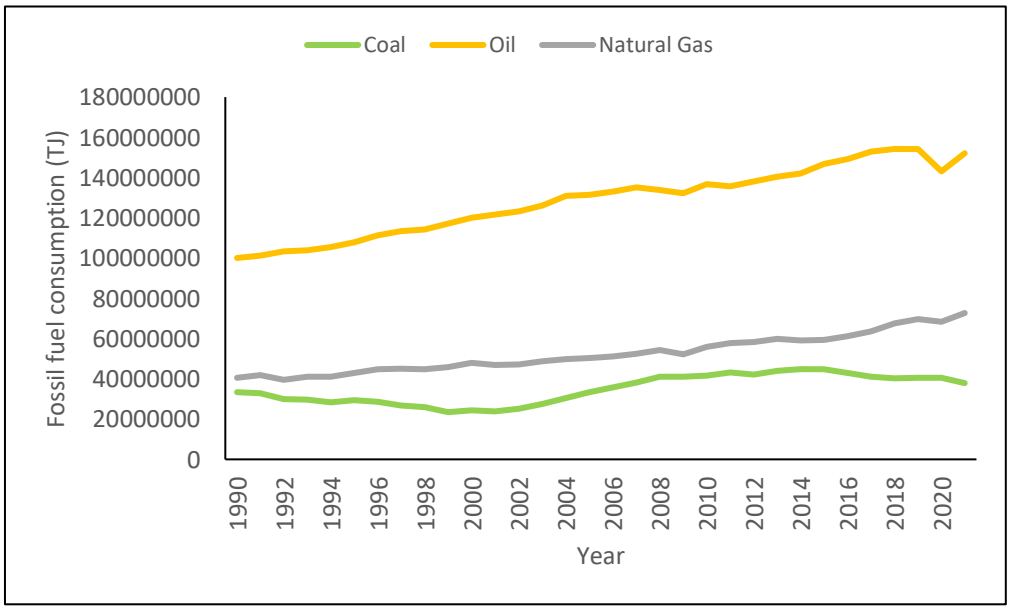
The linkage between industrialization and the environment is multifaceted, having both positive and negative dimensions. Some of the important linkages between them include (a) environmental degradation; (b) climate change; (c) resource depletion, (d) positive technological and environmental advances; (e) economic growth and environmental trade-offs; and (f) urbanization. The present study focuses on the environmental degradation linkage between industrialization and the environment. Environmental degradation caused by industrialization includes the following forms – air pollution, water pollution, deforestation and soil degradation. Industrialization is crucial for attaining economic growth of a nation but at the cost of such environmental degradation. The trade-off arises due to the linkage of industries with the environment.

The industrial revolution in low-income countries involved the setting up of light industries which did not have severe environmental consequences. As these economies started growing, the low-industrialized nations started emphasizing the growth of manufacturing

or heavy-industry products (World Bank, 2009). This pattern of industrialization which has been followed by almost every country in the world, became a great cause of concern for the environment. Heavy industries demand and consume a high volume of energy, which causes pollution, especially in developing countries due to less stringent environmental regulations. Moreover, in developing countries, the dependence on fossil fuels is higher to meet the energy demand of households and industries (Pata, 2018).

Figure 1.4 below represents the consumption of fossil fuels (coal, oil and natural gas) by industries across the globe. Ironically, an upward trend of consumption has been observed for all three fossil fuel energy sources. The industrial consumption of oil is found to be at the highest scale among all. Natural gas and coal come in the second and third places, respectively. This consumption is expected to further rise in the coming future with the growing industrialization in developing economies, coupled with their energy inefficiency and non-availability of adequate renewable energy.

Figure 1.4: Global fossil fuel consumption by industries



(Author's compilation; Source: United Nations Statistics Division)

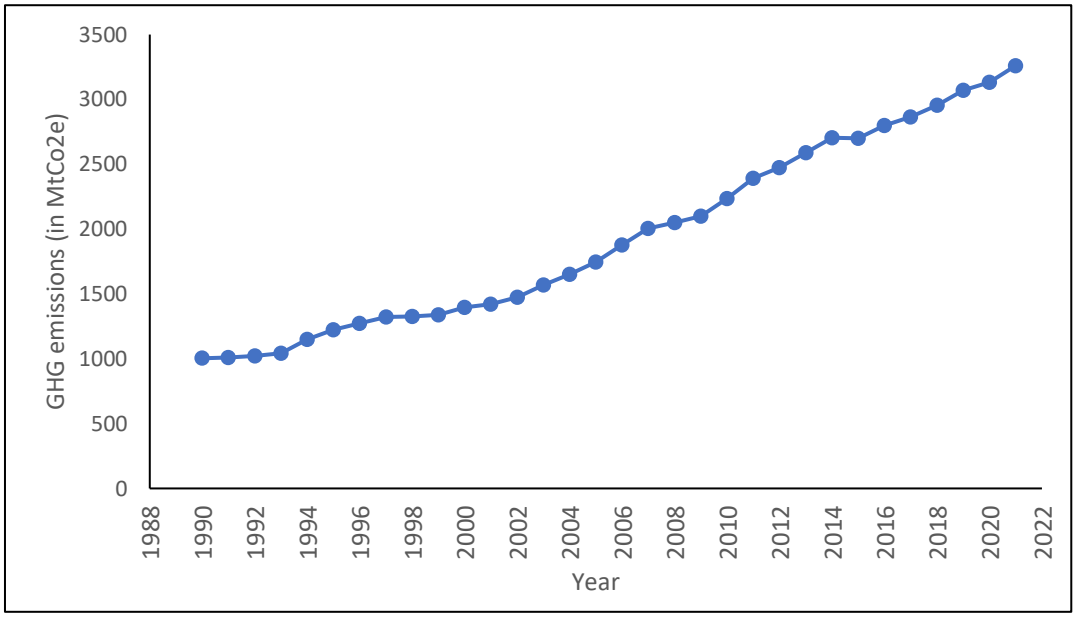
In developing countries, the supply of renewable energy supplies is not sufficient. As a result, industries are compelled to turn to fossil fuel utilization for conducting their industrial operations. Carbon dioxide and other greenhouse gases are released in large quantities during the burning of coal, oil, and natural gas, which contributes to the ongoing climate change and global warming issues. In addition, this process releases nitrogen oxides

and sulfur dioxide into the atmosphere, which are responsible for growing ecological concerns such as smog, acid rain and respiratory problems in urban locations.

Heavy reliance on fossil fuels in industrial activities accounts for rising industrial emissions, particularly carbon emissions. Previous studies have shown how industrialization has significantly contributed to CO_2 emissions in countries (Aslam et al., 2021; Pata, 2018). A report by the Intergovernmental Panel on Climate Change (IPCC) establishes that 24% of total global GHG (greenhouse gas) emissions in 2010 were emitted by industries alone (IPCC, 2014). Fossil fuels are responsible for 75 percent of global GHG emission levels and 90 percent of total global carbon emissions (World Meteorological Organization, 2023). Even the United States (US), a leading developed economy in technology advancement and resource accessibility, faces high emissions from its industrial sector. The US Environmental Protection Agency (EPA) reported that 23 percent of its total CO_2 emission levels have been emitted only by industrial activities in 2021 (EPA, 2023). Similar statistics by the International Energy Agency (IEA) report that the industrial sector across the globe emitted approximately 43 percent of total global carbon emissions in 2017 (International Energy Agency, 2019).

Figure 1.5 below shows that GHG emissions from industrial processes during the period 1990 to 2021 have been significantly increasing at a global level. It is observed that the emission levels have increased significantly by 224.89 percent between 1990 and 2021. The upward trend indicates that industries have failed to curb their emission levels, putting global health at greater risk. The increasing rate of emissions demonstrates a massive jump that requires immediate attention.

Figure 1.5: Greenhouse gas emissions from industrial processes

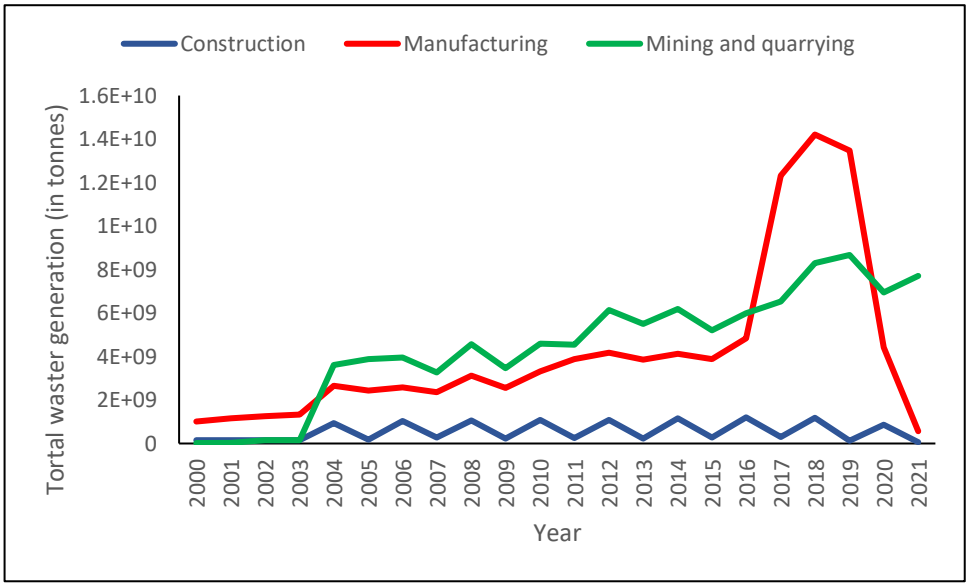


(Author's compilation, Source: Climate Watch database)

In addition to GHG emissions, industrial activities are one of the major sources of particulate matter (PM) emissions. PMs consist of toxic particles made up of chemical components and materials. They are classified based on their particle sizes, such as PM10 (less than 10 micrometres in diameter) and PM2.5 (less than 2.5 micrometres in diameter). Because of their miniature physical characteristics, they can enter the internal body while breathing and reach the lungs or bloodstream, causing serious health issues.

Nonetheless, industries also generate a tremendous deal of waste. If proper filtration practices are not followed and these wastes are released directly into the environment, they pollute both land and water quality. The release of harmful chemicals and pollutants from industrial processes can result in the impurity of soil, water and air. Waste components such as heavy metals, pesticides, chemicals, etc. lead to harmful effects on wildlife, including reproductive failures and genetic mutations. Moreover, the improper handling of industrial waste poses a significant risk to the survival of all species and challenges the resilience capacity of the overall ecosystem. Figure 1.6 shows the waste generation volume of construction, manufacturing and mining and quarrying industries at a global level. These three are regarded as the most highly polluting industries.

Figure 1.6: Waste generation from selected industries



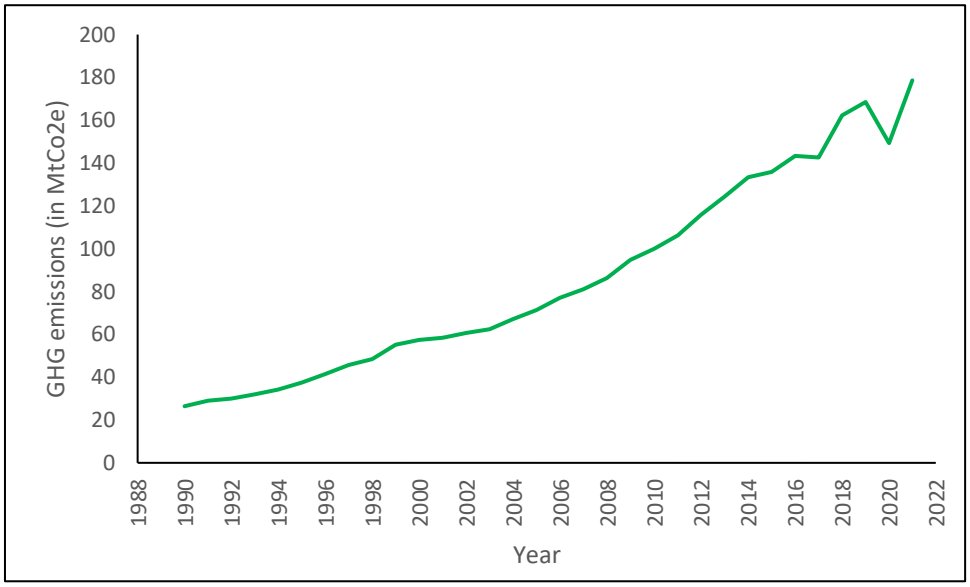
(Author's compilation; Source: SDG indicators database, United Nations)

As observed from Figure 1.6, apart from the manufacturing industry, the other two have shown no significant improvement in their waste management competence from 2000 to 2021.

Thus, the linkage between industrialization and the environment has been exacerbated in the form of environmental degradation. GHG emissions are the major channels of environmental degradation by industries.

The Indian context: The IEA has reported that CO_2 emission levels have witnessed a remarkable growth of 4.2% in Asian emerging countries (excluding China) in 2022, which is more than any other region in the entire world (IEA, 2023). It also reports that more than half of this escalation is caused by coal-fired energy sources. From 2000 to 2017, one-half of the global emission increase was due to greater power generation in Asia. Likewise, India's industrial energy demands are mostly fulfilled by electricity and coal consumption. While many countries have shown improvements in their energy efficiency, India has tripled its energy consumption levels without significant improvement in energy efficiency (International Energy Agency, 2019). In India, 89.36 percent of total primary energy consumption was facilitated from fossil fuel sources in 2021 (Energy Institute Statistical Review of World Energy, 2023). India has miserably failed to reduce its reliance on fossil fuels, which is the primary reason for its high industrial emissions. Figure 1.7 demonstrates that India's GHG emissions from industrial processes increased significantly from 1990 to 2021, with an increase of approximately 575.27 percent over these three decades.

Figure 1.7: Greenhouse gas emissions from industrial processes in India



(Author's compilation; Source: Climate Watch database)

Moreover, as a developing economy, India lacks various facilities such as advanced technologies, access to environmentally friendly resources, awareness and alertness of ongoing environmental issues among stakeholders, etc. Given these issues, it becomes even more difficult for the country to protect its environment from industrial emissions. India has been marked as the third-highest CO_2-emitting country in 2021 and also, due to the massive usage of fossil fuel energies by the Indian industries, India accounted for 7% of the global fossil CO_2 emissions (Global Carbon Project, 2022).

In terms of extreme climate change vulnerability, India is ranked seventh in the world by the Global Climate Risk Index 2021 (Eckstein et al., 2021). The report emphasizes its economic relevance, noting that India must deal with losses and damages of approximately USD 8–9 billion annually as a result of the country's current harsh climate conditions. The Council on Energy, Environment, and Water (CEEW) has identified 75% of Indian districts as hotspots for these types of distressing climate situations (Mohanty & Wadhawan, 2021). The majority of India's population depends on rural activities such as agriculture, fishing, forestry and related services, which are climate-sensitive. Therefore, these conditions will have a greater effect on the nation's population. Furthermore, the increasing disparity in political, social and economic circumstances between India's rural and urban populations impacts the ability of the locals to adapt to these environmental difficulties. These environmental circumstances have led to the deaths of humans and other living beings on a regular basis in India (Mehta et al., 2022). It demonstrates India's very sensitive

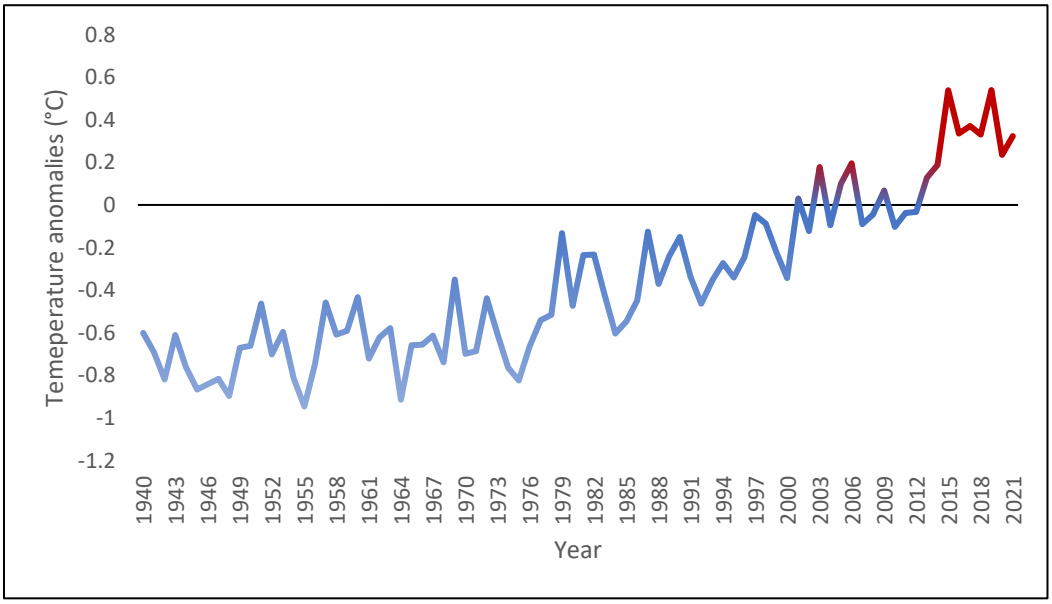
environmental position. Being the third-highest carbon-emitting country, India's environmental responsibilities are not limited to its people alone but towards the health of the entire ecosystem worldwide. India updated its Nationally Determined Contribution (NDC) targets to lower its carbon intensity level by 45% by 2030 during the 2021 United Nations Climate Change Conference, popularly known as COP26, which was held in Glasgow. The nation also hopes to achieve net-zero emissions by 2070 (Government of India, 2022). In order to achieve such ambitious targets, the Indian industries must take full responsibility and accountability to build a greener economy.

1.4. Environmental degradation:

Some of the major concerns arising out of environmental degradation are discussed in this section. Global warming and climate change have caused disbalance in the entire ecosystem worldwide. The rise of GHGs in recent decades has led to several survival-threatening environmental consequences around the world (IPCC, 2019b; Sanjuán et al., 2020). GHGs absorb heatwaves that enter the atmosphere of the earth and trap them within, creating greenhouse effects (IPCC, 2019a, 2023). Among all GHGs, carbon dioxide has always been considered the major contributor to the ongoing global warming issues (IEA, 2023; IPCC, 2014), as it is the main greenhouse gas emitted from human activities. The increase in greenhouse gas concentration since the industrial revolution has caused a manifold increase in the earth's temperature leading to climate change. This has detrimental consequences on both land and water inhabitants. Researchers have expressed concerns that with the prevailing situation, the global temperature will continue to rise in the coming years, leading to the vulnerability of life on earth. GHGs emitted from human activities are popularly known as anthropogenic emissions and they are the root cause of growing global temperature. In this section, some of the environmental hazards that have occurred to land and water ecosystems are discussed.

Rising temperature on earth: Reports have documented that the world has already reached a global temperature increase of 1.1°C by 2021 (IPCC, 2021). Figure 1.8 demonstrates the anomalies or deviations in the global temperature from the average temperature of 1991-2020. It indicates how global temperature has been on a constant rise and humankind is failing to prevent such a disastrous event.

Figure 1.8: Global temperature anomalies

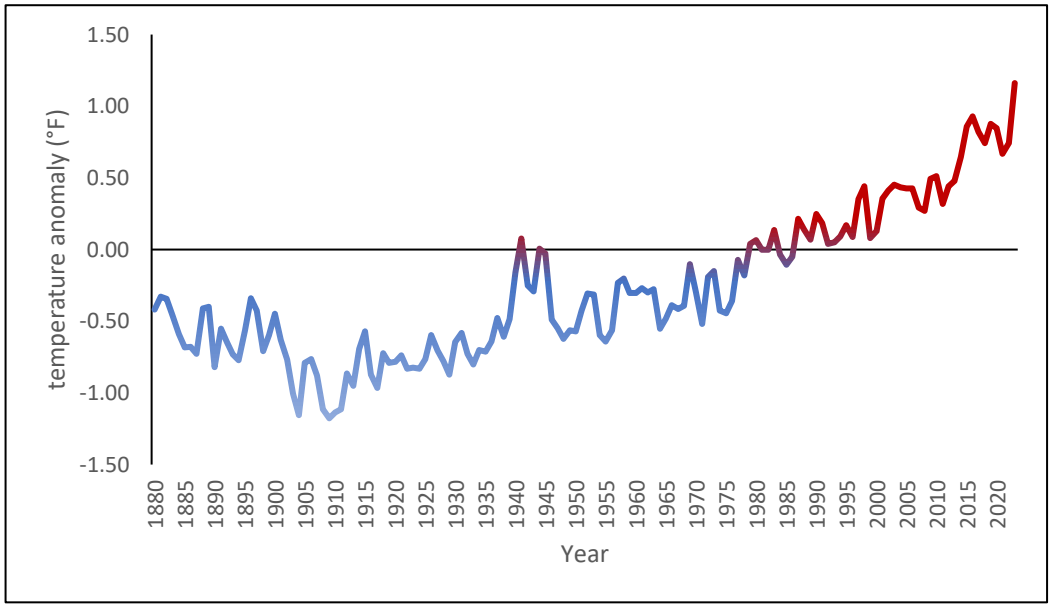


(Author's compilation; Source: National Oceanic and Atmospheric Administration, 2024)

In recent years, the temperature has increased at a steeper rate causing greater deviations in the global temperature as seen in Figure 1.8 above, threatening the world's environmental health like never before. According to the World Health Organization, 24% of total estimated global deaths have occurred due to various environment-related issues (Prüss-Ustün et al., 2016). From a global perspective, 3.6 billion people live in areas that are vulnerable to ongoing climate change concerns. If the situation is not controlled, the volume of deaths from climate change consequences may lead to approximately 2,50,000 additional deaths per year between 2030 and 2050. The number of estimated deaths demonstrates the urgency of the current situation. Such conditions will pose greater threats for developing countries where the health sector's infrastructure is not up to par (IPCC, 2023).

Rise in sea level temperature: Ocean bodies contribute significantly to the maintenance of overall environmental health by absorbing around 90% of the earth's heatwaves. However, with the rising ocean warmth, marine heatwaves have become more intense and frequent. From 2011 to 2020, 60% of the world's ocean surface is already affected by the heatwaves. Figure 1.9 shows the global sea surface temperature anomaly or deviation from 1880 to 2023.

Figure 1.9: Average global sea surface temperature (1880–2023)



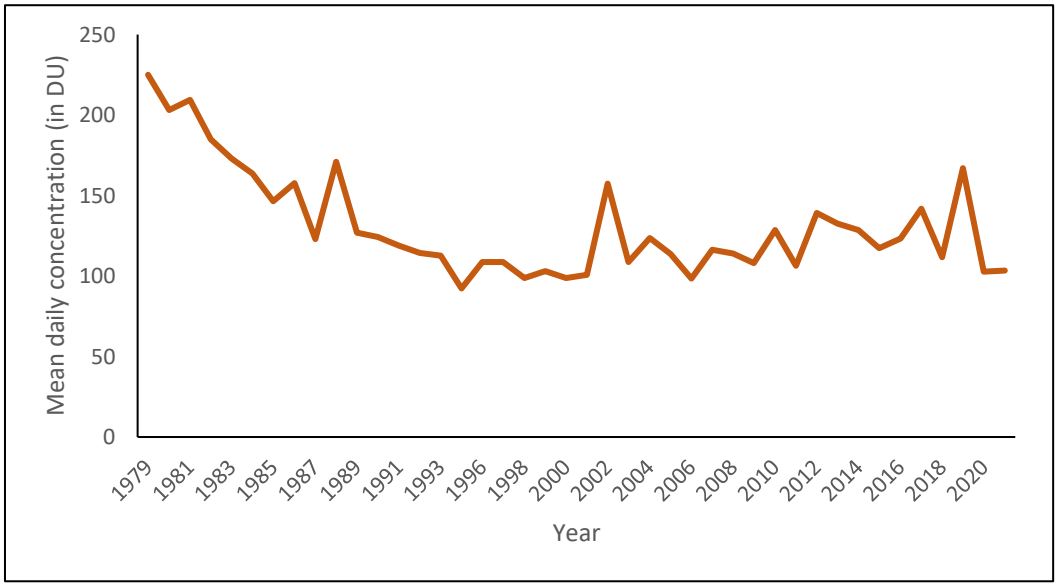
(Author's compilation; Source: National Oceanic and Atmospheric Administration, 2024)

The figure clearly portrays how the temperature of the water bodies has increased over the past few decades. The rising temperature trend has become steeper in recent years, confirming the need for immediate action to rectify this situation. Otherwise, heat waves in the oceans and seas would increase the mortality rates of marine animals and plants.

Ozone layer depletion: Ozone depletion is another significant environmental consequence of human activities (Cramer & Cheney, 2000; Ravishankara et al., 2009). The ozone layer present in the stratosphere is known for barring excessive heatwaves and ultraviolet rays from entering the earth's surface. However, as a result of anthropogenic air pollution, the ozone layer has started depleting, presenting new challenges for the world to balance environmental health (Stolarski et al., 2015). The loss of ozone layers can cause diseases like skin cancer and cataract issues by allowing harmful ultraviolet rays to pass into the earth's close atmosphere. Not only human beings but the growth of plants and crops have also shown irregularities towards exposure to ultraviolet rays. Similarly, the marine ecosystem has also been threatened by such depletion issues.

Figure 1.10 shows that the concentration of the ozone layer has decreased over the years from 1979 to 2021. Lower ozone concentration is harmful to the environment, as it lets harmful ultraviolet rays pass into the earth's atmosphere on a greater scale.

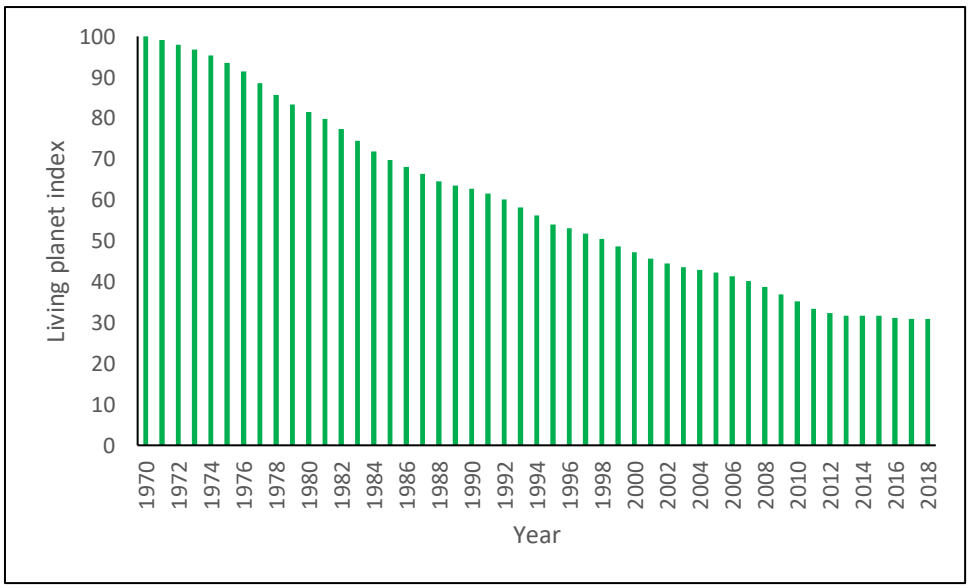
Figure 1.10: Concentration of ozone in the stratosphere



(Author's compilation; Source: NASA Ozone Watch, 2024)

Biodiversity loss: Global warming has caused an imbalance in the entire biodiversity, making it difficult for certain species to survive in extreme conditions. Figure 1.11 shows that there is a clear decline in the living planet index from 1970 to 2018, where the index value has declined by an average of 69 percent. The index considers 1970 to be its base year and shows the relative changes in the population of various animal species thereafter.

Figure 1.11: Global Living Planet Index



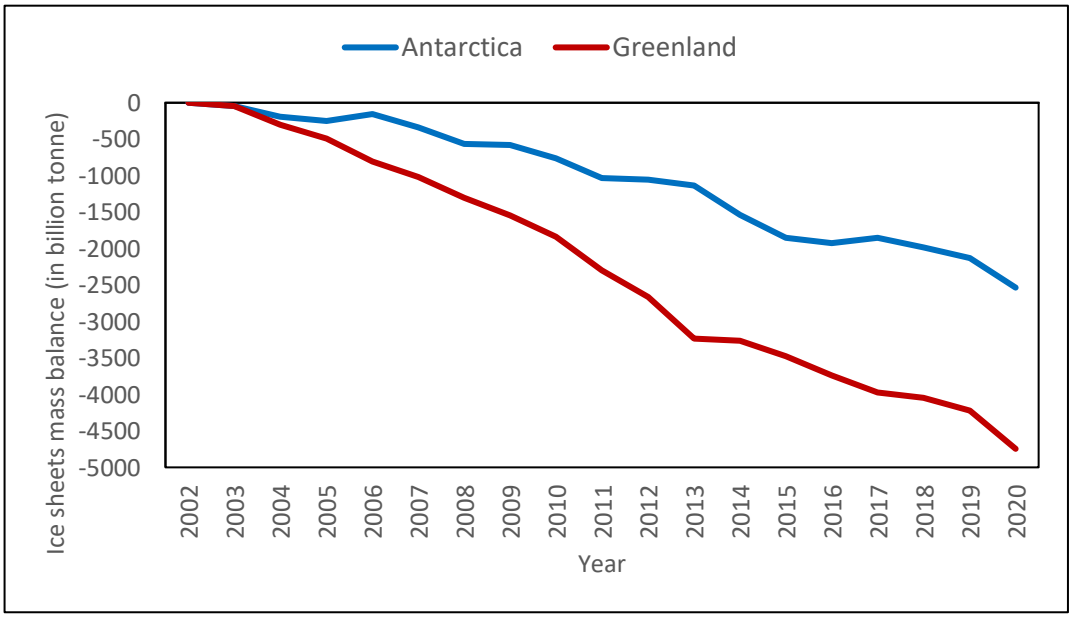
(Author's compilation; Source: World Wildlife Fund and Zoological Society of London)

The occurrence of heatwaves, landslides, floods, hurricanes, wildfires and tropical storms has become unstable due to extreme weather conditions and their magnitude and frequency

have been on the rise lately. Such events cause an imbalance in the entire ecosystem of any geographical location, leading to unimaginable destruction. While the fall of the Living Planet Index may not entirely be due to ongoing environmental issues, these issues are certainly one of the most significant causes. According to United Nations estimates, humankind has already transformed or affected over 70 percent of the world's ice-free lands, posing a threat to the survival of various animal and plant species. These are mostly the consequences of land usage for agricultural activities, leading to deforestation.

Melting of glaciers: The most vulnerable regions of the ongoing climate shifts have been the northern and southern poles. The melting of glaciers and ice sheets in the polar regions due to rising heat has raised global environmental risks. It not only affects the ocean biodiversity but also invites survival threats to the coastal and low-lying areas (IPCC, 2007). The glacier sheets help maintain the earth's temperature by reflecting the heatwaves without their absorption. The melting of these sheets invites risks of temperature imbalance, which has already started reflecting in today's world. As a result, it creates a chain reaction affecting all marine living beings. It can create further issues of food insecurity, loss of agricultural productivity, threatening the existence of biodiversity, etc., which are explained in detail in the preceding sections. Another severe consequence of these ice sheet melts is the rise in sea levels. Figure 1.12 displays how the ice sheets from Antarctica and Greenland are constantly melting over the years.

Figure 1.12: Ice sheets melting in Antarctica and Greenland

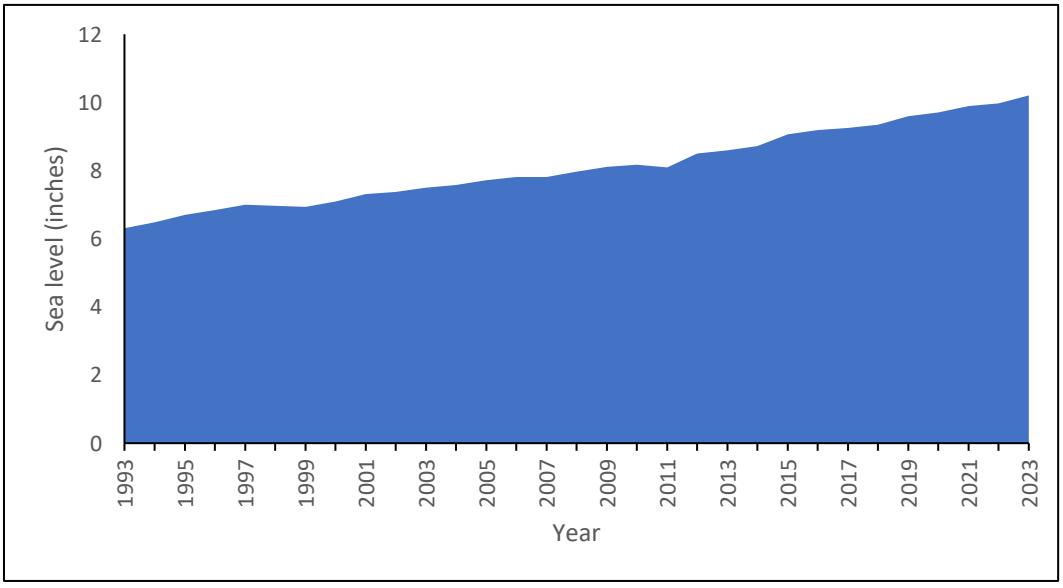


(Author's compilation; Source: United States Environmental Protection Agency)

The figure presents the cumulative change in these ice sheets by considering 2002 as the base year at point zero. These two ice sheets are considered the largest in the world, and their melting will undoubtedly pose greater environmental challenges.

Rising sea levels: The sea level has risen at an annual rate of 4.5 mm from 2011 to 2020 (World Meteorological Organization, 2023). This sea level expansion is the result of two primary causes. Firstly, the increasing warmth of the sea surfaces. When the water temperature rises, it contributes to rising sea levels through thermal expansion. Secondly, the melting of polar ice sheets. Not only for the marine bodies, but its effects have become slowly visible on land locations too, leading to extreme weather conditions like hurricanes, floods, landslides, storms, etc. In the 20th century, sea level has shown a continuous rise due to the melting of ice and thermal expansion from heat. Figure 1.13 illustrates that the rate of increase in absolute sea level has accelerated in recent years. Absolute sea level rise indicates the elevation of the sea surface from the centre of the earth, irrespective of the changes in the height of the adjacent land areas. Given the ongoing conditions, the World Meteorological Organization (WMO) has predicted that the oceans will rise 1.6 to 6.6 feet by 2100. If this becomes a reality, it will perish the coastal locations and low-lying areas across the globe. The island nations will also not be safe from such consequences. The prediction also threatens the destruction of renowned cities such as Mumbai, Los Angeles, Miami, New York, Rio de Janeiro, Sydney, and so on due to rising sea levels (World Meteorological Organization, 2023).

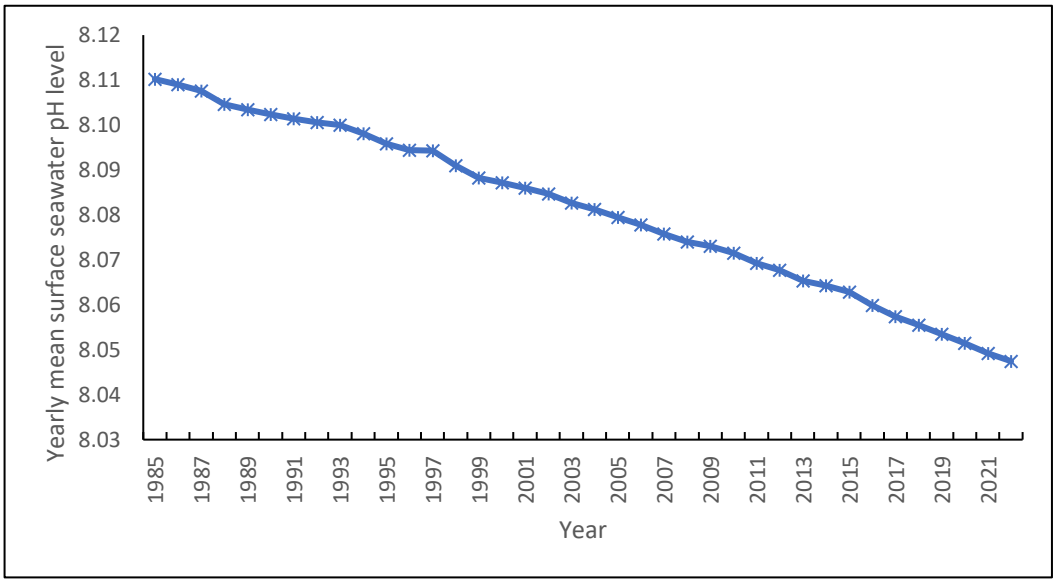
Figure 1.13: Global Average Absolute Sea Level Change, 1880–2023



(Author's compilation; Source: National Oceanic and Atmospheric Administration, 2024)

Ocean acidification: Oceans and seas are known for absorbing a large portion of carbon dioxide from the atmosphere and capturing the heat disseminated from the same. When these water bodies absorb extreme carbon dioxide and heat waves, it causes chemical reactions and acidification of the water resources (Hassoun et al., 2022; Kroeker et al., 2013). It has destructive effects on life underwater. It also impacts the land ecosystem by reducing the ocean's carbon-absorbing capacity. The oceans and seas help remove a considerable amount of carbon emissions from the atmosphere to maintain environmental harmony. Due to the acidification of the water bodies, such balance has been compromised. During the pre-industrial period, the average pH level of the ocean bodies was 8.2. However, the average pH level in 2022 is found to be 8.1, proving that the ocean bodies have become 30 percent more acidic after the industrial revolution. According to estimates, the pH level will reach 7.8, making the water bodies 150 percent more acidic. It will undoubtedly cause a massive imbalance, not only among marine biodiversity but also in land habitats (IPCC, 2023). Figure 1.14 illustrates the decreasing pH level of global sea surfaces. The issue requires more attention before the acidification level grows in the coming years.

Figure 1.14: Global seawater acidification level



(Author's compilation; Source: Copernicus Marine Environment Monitoring Service)

In the figure above, we see a declining trend of pH levels in global seawater surfaces. The lower the pH level, the higher the acidification rate. Hence, the declining pH levels indicate rising acidification of the seawater surfaces from 1985 to 2022.

Impact on agriculture: Climate change and extreme weather conditions also impact economic activities (Chen et al., 2016). Their downturn effects have been observed in the agriculture sector, threatening food security for all beings (Malhi et al., 2021; Syed et al., 2022). The productivity of the agricultural sector has been negatively affected due to unexpected heavy rainfalls, floods, changes in temperature, etc. (Chandio et al., 2020; Ullah et al., 2016). In the presence of high air pollution, plants show slow growth and higher chances of being affected by diseases. The unpredictable weather events provide farmers with less opportunity to take the necessary precautions for plants' healthy growth. As a result, insects, weeds and diseases in crops and plants have increased. Likewise, wildfire events entirely destroy the farmlands and grasslands, reducing their productivity levels with certainty for upcoming years. The rising levels of water bodies have also become a hindrance to agricultural productivity. Because of heavy rainfalls and ice melting, water runoff occurs more frequently in agricultural land areas.

1.5. Environmental protection:

Rising global temperatures have caused extreme weather conditions across nations, creating unpredictable natural events (World Meteorological Organization, 2023). Key measures adopted by various international organizations working towards environmental protection are noteworthy. Likewise, countries across the globe have come together in various forums to take collective measures to protect the globe from such environmental destruction. The Intergovernmental Panel on Climate Change (IPCC) has become the leading organization which is actively involved in safeguarding global environmental health since 1988. It was formed by the joint efforts of the WMO and the United Nations Environment Program (UNEP). Apart from offering suggestions and opinions on sustainability, the IPCC has been releasing a positive number of significant reports that have successfully highlighted the weight of the ongoing environmental issues. The organization also specifically focuses on individual countries and their industrial profiles to make the world aware of their sustainable position. These reports help the concerned authorities know where those countries or industries stand and what can be done to improve their environmental efficiency levels. Another noteworthy foundation is the United Nations Framework Convention on Climate Change (UNFCCC). Signed in 1992, the UNFCCC is most popular due to its recognized contribution towards world sustainability through the events of the Kyoto Protocol in 1997, the Paris Agreement in 2015 and its yearly Conference of the Parties (COP). The Kyoto Protocol was adopted in 1997 but was

enforced in 2005. It is recognized as the first major international agreement among the member countries that set mechanisms for the growing industrialized economies to limit their emission levels, anticipating these countries' role in building future environmental health. It introduced the Clean Development Mechanism (CDM) projects that laid the foundation for the popular carbon trading structure. The idea was to help industries across nations to allow for cost-effective efforts for taking responsibility for their emission mitigations. The ambitions of the Kyoto Protocol led to the occurrence of the Paris Agreement in 2015, which was adopted at COP21 held in France. This agreement is probably the most popular event related to climate change action to date. It successfully highlighted global warming and climate change concerns among developing and developed nations on a remarkable level. The agreement officially recognized the idea of carbon mitigation so that the global temperature does not exceed 2°C compared till the pre-industrial era. To keep this target safe, the agreement urged its members to make every effort to limit the temperature increase to 1.5°C at any cost. The participant countries were advised to set their Nationally Determined Contributions (NDCs) as an outcome of the agreement so that each of them could set their distinctive targets to contribute towards sustainability. The Paris Agreement played an active role in appealing to the developed countries for financial and non-financial support to the less developed and developing economies for financing their eco-friendly projects. Overall, the agreement was necessary for building an internal network among the nations so that climate actions could be acted upon collectively on a global scale for a safer and greener future.

Later in 2015, the United Nations Member States introduced 17 Sustainable Development Goals (SDGs) to achieve the 2030 Agenda for Sustainable Development, aiming at peace and prosperity for people and the planet. The SDGs have also added significant value to the ongoing climate change movements, where the relevance of a healthier environmental condition is discussed for providing all people a chance to have an equitable and peaceful life. SDG 9 of the United Nations focuses on attaining sustainable industrialisation through increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes. This requires a significant reduction in the intensity of industrial carbon emissions. Sustainable industrialization refers to the attainment of industrial growth without compromising the ecological balance and social well-being of the people. The core belief of sustainable industrialization is the adoption of cleaner production mechanisms through resource efficiency, technological upgrades and waste

minimization. The generation and consumption of renewable energy sources are vital in achieving sustainable industrialization.

1.6. Statement of the problem:

India is one of the fastest-growing economies in the world. In 2021, industrialization contributed 26.47 percent to the country's GDP, which is still lower than the service sectors' contribution of 47.85 percent. Industrialization is crucial for attaining economic growth as it leads to improved productivity, higher standards of living, greater wealth, infrastructure development, etc. Hence, India needs to prioritize achieving greater industrial growth. Nevertheless, the focus should be on sustainable industrialization to ensure environmental sustainability along with economic growth. Sustainable industrialization is a continuous process. It has to be integrated with all sectors of the economy to realize the true benefits of sustainable industrialization.

Although previous literature has discussed the various dimensions of sustainable industrialization in India, the case of the core industries remains completely unexplored. The present study, therefore, endeavours to assess the industrial sustainability of the core industries in India.

Assessing the trend of carbon emissions can offer a true picture regarding the pollution levels of the industries. As CO_2 is the most dominating GHG, knowledge of the industries' carbon emission levels is critical to take measures towards sustainable industrialization. Along with the trend, the assessment of the carbon efficiency levels of the core industries can further add significance to the assessment of sustainable industrial practices of the core industries. Based on their efficiency levels, specific measures can be adopted for high-polluting industries.

To achieve sustainable industrialization, it is vital to understand how the various economic, industrial, demographic and environmental factors can impact the carbon emission levels of the core industries. Accordingly, required policies can be formulated to improve the core industries' environmental performance.

Investigating the linkage between industrialization and environmental degradation levels can provide deeper insights into sustainable industrialization of the core industries. It can also indicate the threshold level of the growth of the core industries, critical for achieving environmental sustainability. Environmental sustainability necessitates the early attainment

of the threshold level of industrial growth. The government of the country can play a significant role in this context through measures such as the implementation of environmental policies and improvement in industrial structure. Investigating the moderating roles of environmental policy stringency and industrial structure improvement in the relationship between industrial growth and emission levels can further add to the understanding and assessment of sustainable industrialization.

1.7. Research gap:

After reviewing the existing literature, the following research gaps are identified to be addressed in the present research work:

- Although studies have focused on the EKC hypothesis for different geographical locations, only limited studies have addressed the applicability of the IEKC in examining industrial sustainability. Besides, no such studies have been found in the Indian context.
- Focus on the environmental impact of the Indian core industries is utterly negligible in the prior literature.
- Studies were found using the decoupling approach for analyzing an economy's environmental efficiency. Very few studies have adopted it to assess the environmental efficiency of industries.
- Studies have mostly considered economic determinants of industries' environmental degradation. However, studies addressing the role of factors such as industrial design, certified emission reductions (CERs), education, poverty, etc. have not been found, particularly in the Indian context.
- Studies have not explored the moderating roles of environmental policy stringency and industrial structure improvement in the relationship between industrial growth and environmental degradation.
- Contemporary literature has explored the existence of an N-shaped EKC in countries. Limited studies have been found that looked into the N-shaped IEKC for industries and no such studies could be found in the Indian context.

1.8. Research questions:

The present research work attempts to find answers to the following research questions that are raised based on the research gap in the existing literature:

- What are the carbon emission levels of the core industries in India?
- What are the economic factors affecting the Indian core industries' carbon emission levels?
- What are the industrial factors affecting the Indian core industries' carbon emission levels?
- What are the demographic factors affecting the Indian core industries' carbon emission levels?
- What are the environmental factors affecting the Indian core industries' carbon emission levels?
- What is the relationship between the core industries' growth and their carbon emission levels?
- What is the moderating role of environmental policy stringency in the relationship between the core industries' growth and their carbon emission levels?
- What is the moderating role of industrial structural improvement in the relationship between the core industries' growth and their carbon emission levels?

1.9. Research objectives:

The present research work aims to fulfil the following objectives:

1) To compare the levels of carbon emissions across core industries.
2) To identify the driving forces of carbon emissions in the core industries.
3) To analyze the relationship between industrial growth and environmental degradation in the core industries.

1.10. Research hypothesis:

In order to fill the identified research gaps and to seek answers to the above-mentioned research questions, the following hypotheses are formulated to be empirically investigated by the present research work:

***H*$_{2.1}$**: There exists a significant positive relationship between economic growth and core industries' carbon emission levels in India.

$H_{2.2}$: There exists a significant positive relationship between FDI and core industries' carbon emission levels in India.

$H_{2.3}$: There exists a significant positive relationship between agricultural production and core industries' carbon emission levels in India.

$H_{2.4}$: There exists a significant negative relationship between R&D and core industries' carbon emission levels in India.

$H_{2.5}$: There exists a significant positive relationship between industrialization and core industries' carbon emission levels in India.

$H_{2.6}$: There exists a significant positive relationship between energy consumption and core industries' carbon emission levels in India.

$H_{2.7}$: There exists a significant negative relationship between financial support and core industries' carbon emission levels in India.

$H_{2.8}$: There exists a significant negative relationship between industrial design and the core industries' carbon emission levels in India.

$H_{2.9}$: There exists a significant positive relationship between population density and the core industries' carbon emission levels in India.

$H_{2.10}$: There exists a significant positive relationship between urbanization and the core industries' carbon emission levels in India.

$H_{2.11}$: There exists a significant positive relationship between poverty and the core industries' carbon emission levels in India.

$H_{2.12}$: There exists a significant negative relationship between education and the core industries' carbon emission levels in India.

$H_{2.13}$: There exists a significant positive relationship between tree cover loss and the core industries' carbon emission levels in India.

$H_{2.14}$: There exists a significant positive relationship between water stress and the core industries' carbon emission levels in India.

$H_{2.15}$: There exists a significant negative relationship between environmental technology and the core industries' carbon emission levels in India.

$H_{2.16}$: There exists a significant negative relationship between CER and the core industries' carbon emission levels in India.

$H_{3.1}$: There exists a significant inverted U-shaped relationship between the core industries' growth and their emission levels.

$H_{3.2}$: There exists a significant negative moderating role of environmental policy stringency in the relationship between the core industries' growth and their emission levels.

$H_{3.3}$: There exists a significant negative moderating role of industrial structural improvement in the relationship between the core industries' growth and their emission levels.

$H_{3.4}$: There exists a significant N-shaped relationship between the core industries' growth and their emission levels.

1.11. Limitations of the study:

The present research work underlines its primary motivation to explore the environmental dynamics of the Indian industries, considering their role in both economic growth and the environmental health of the nation. Despite the best efforts of the researcher, there remain certain limitations. Firstly, the present study considers the eight core industries of India as its study sample, based on the fact that they contribute the most towards the nation's economic growth and are also highly polluting in nature. However, the core industries represent approximately 40.27 percent of the overall industrial growth in India. The evaluation of the environmental sustainability of the country's remaining industries remained outside the ambit of the present study. The inclusion of other industries will provide a more comprehensive understanding of sustainable industrialization in India that will benefit policymakers to acquire greater insights and adopt effective measures.

Secondly, there are other harmful components or pollutants released by industrial operations whose exploration is equally significant, such as particulate matter, sulfur oxides, chemicals, wastes, nitrogen oxides, etc. Each of these components is emitted on varied scales, imposing different threats on the health of the ecosystem. Although carbon dioxide is recognized as a standard measure for environmental degradation levels, the present study has adopted it as the only indicator of environmental degradation.

Similar investigations must be undertaken in order to ensure inclusive sustainable industrial growth. The researcher believes that the present study will encourage future research work covering these industrial and environmental aspects upon the availability of the required data, which will surely add noble value to the existing literature.

1.12. Plan of the study:

The present research work is structured to be reported into seven chapters. They are:

- Chapter 1: Introduction
- Chapter 2: Review of literature
- Chapter 3: Research methodology
- Chapter 4: Comparison of industrial carbon emissions across the Indian core industries
- Chapter 5: Driving factors of carbon emissions in the Indian core industries
- Chapter 6: Industrial growth and environmental degradation in the Indian core industries
- Chapter 7: Conclusion