

Theoretical framework for assessing the economic and environmental impact of water pollution: A detailed study on sustainable development of India

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ABSTRACT

This research paper aims to explore the relationship between water pollution and sustainable development. Water pollution is a significant environmental challenge that threatens the sustainability of ecosystems, human health, and economic development. Sustainable development aims to meet the needs of the present generation without compromising the ability of future generations to meet their own needs. The research methodology involves a comprehensive review of relevant literature on water pollution and sustainable development, including empirical studies, theoretical frameworks, and policy documents. The research will explore the impact of water pollution on sustainable development, the drivers of water pollution, and the policy and regulatory frameworks that promote sustainable water management. The findings of this research paper will contribute to a deeper understanding of the complex relationship between water pollution and sustainable development and provide insights into effective strategies and policies that can promote sustainable water management. The research will also highlight the importance of public awareness and education in promoting sustainable practices and behaviors that can help to prevent and mitigate water pollution. This research paper will provide valuable insights into achieving sustainable water management practices that promote environmental sustainability and socio-economic development.

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1. Introduction

Water pollution is a significant environmental challenge that affects the quality and accessibility of water resources, posing a threat to the sustainability of ecosystems and human health. It is the introduction of harmful pollutants into water bodies, such as ponds, canals, oceans, and groundwater, which can occur through various human activities such as industrial processes, agronomic practices, and inappropriate dumping of waste (Lam & Li, 2019). The pollutants can be chemical, biological, or physical, and can lead to a range of negative impacts such as the death of aquatic life, the spread of waterborne diseases, and the adulteration of drinking water supplies. Water pollution is a growing concern globally, with many countries facing increasing challenges in managing water quality. The impacts of water pollution are particularly severe in developing countries, where access to safe and clean water is limited, and water pollution poses a significant threat to public health and economic development (Omer & Noguchi, 2020). Water pollution is also a major threat to the sustainability of ecosystems, affecting the ability of aquatic habitats to provide essential services such as fisheries, water supply, and recreation. Sustainable development recognizes the interdependence of environmental, social, and economic systems, and seeks to promote a balance between these systems to ensure long-term sustainability. The aim of ecological growth is to accomplish a future where all people can live fulfilling lives within the ecological limits of the planet (Kalpande & Toke, 2021). Sustainable development can be defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”.

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Sustainable development encompasses a widespread variety of disputes, including environmental protection, social equity, economic growth, and cultural preservation. It requires a holistic and integrated approach that recognizes the interdependence of these issues and seeks to promote their balance. Sustainable development is related to the issue of water pollution, as it recognizes the importance of protecting and restoring natural resources for the long-term benefit of society and the environment (Lacey-Barnacle et al., 2020). Water pollution poses a significant risk to the sustainability of ecosystems and human health, and addressing this challenge is critical to achieving sustainable development goals. Water pollution is the introduction of harmful pollutants into water bodies, which can occur through various human activities (Davies and Mazumder, 2003; Laudon, 2016). The pollutants can be chemical, biological, or physical, and can lead to a range of negative impacts such as the death of aquatic life, the spread of waterborne diseases, and the contamination of drinking water supplies.

Sustainable development requires the adoption of environmentally responsible practices that promote the protection and restoration of natural resources, including water (Laudon et al., 2016). Achieving sustainable development in relation to water pollution requires the collaboration of governments, businesses, civil society, and individuals to develop and implement sustainable policies and practices. This may include measures such as reducing the usage of harmful chemicals, improving wastewater treatment, and promoting sustainable agriculture practices (Alcamo, 2019). The adoption of sustainable development practices in relation to water pollution is critical to ensuring a sustainable future for all.

1.1. Water contamination data from the United Nations on sustainable development

The United Nations (UN) tracks data on sustainable development goals, including those related to water pollution. Here are some key statistics and information. Target 6.3 of the UN's ecological expansion goals aims to "improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally by 2030" (Alcamo, 2019; Zalidis, 2002). Water pollution can have serious health and environmental consequences, including increased risks of waterborne diseases, harm to aquatic ecosystems, and damage to crops and other agricultural resources. Many countries have made progress in addressing water pollution, but much work remains to be done. For example, one 2021 report from the UN Environment Program found that only 43% of countries have implemented policies to address the major sources of marine plastic pollution (Shrivastava, 1995; Belayutham, 2016). To address water pollution, the UN recommends a range of interventions and reducing the use of hazardous chemicals in industry.

India is a country that faces significant challenges related to water pollution. Here are some key statistics and information related to sustainable development on water pollution in India, as reported by the United Nations (UN): According to a report, around 70% of India's surface water resources are polluted (Kalpande & Toke, 2021; Lacey-Barnacle et al., 2020). This is due to a combination of factors, including untreated sewage and industrial effluents. The UN reports that water pollution is a significant contributor to disease and mortality in India, particularly in rural areas. The Indian government has launched several initiatives to address water pollution, including the National River Conservation Plan and the National Water Quality Sub-Mission (Zalidis, 2002; Belayutham, 2016). However, these efforts have been hindered by a lack of funding and inadequate infrastructure.

In recent years, there has been growing public awareness and activism around water pollution in India, with campaigns and protests drawing attention to issues such as industrial pollution and groundwater depletion.

1.2. Initiatives taken by Indian government to reduce water pollution issues

There is a significant amount of data on sustainable development and water pollution in India. Here are a few sources where you can find more information.

- **Central Pollution Control Board (CPCB):** The CPCB is the apex pollution control board in India, and they collect data on water pollution from several sources such as industries, sewage treatment plants, and rivers. Their website has reports, publications, and real-time data on water quality across the country (Swinton, 1999; Price, 2015).
- **Global Water Intelligence:** Global Water Intelligence is a business information company that provides news, reports, and analysis on the water industry. They have published numerous reports on water pollution in India addressing the opportunities and challenges associated with sustainability (Reddy & Behera, 2006).
- **World Bank:** The World Bank has provided financial assistance to India for various projects related to water management and pollution control. Their website has reports on these projects, including data on water quality and pollution (Kalpande & Toke, 2021; Price, 2015).
- **India Water Portal:** This is a website that provides comprehensive information and resources on water-related issues in India, including water pollution. They have data on water quality monitoring, pollution sources, and measures taken to control pollution (Halder & Islam, 2015; Tran, 2002).
- **United Nations Development Programme (UNDP):** The UNDP has been working with the Indian government on various sustainable development projects, including water management and pollution control. Their website has reports and data on these projects and their impact (Goswami et al., 2022).

- **Centre for Science and Environment (CSE):** The CSE is a non-profit organization that works on environmental issues, including water pollution. They have published reports on various aspects of water pollution in India, such as industrial pollution, sewage treatment, and river pollution (Sahoo & Choudhury, 2022; Vijay et al., 2011).
- **The Energy and Resources Institute (TERI):** TERI is a research institute that works on sustainable development issues, including water management and pollution control. They have published research papers and reports on several phases of water pollution in India, such as the use of new technologies for pollution control and the impact of climate change on aquatic resources (Liu et al., 2020; Duttagupta et al., 2020).

1.3. Significance of sustainable development

Sustainable development is crucial for addressing the issue of water pollution. Here are some significant ways in which sustainable development can help to reduce water pollution.

1. **Encouraging responsible and sustainable use of water resources:** Sustainable development advocates for the responsible use of water resources to prevent their depletion and pollution. By promoting water conservation and efficient water usage, sustainable development can reduce the amount of wastewater produced and, consequently, decrease water pollution (Jalil, 2010; Dwivedi, 2017).
2. **Reducing plastic waste:** Plastic pollution is a significant problem in water bodies, leading to severe environmental and health impacts. Sustainable development emphasizes the need to reduce plastic waste through recycling, reusing, and reducing the use of single-use plastics, thereby reducing the amount of plastic that ends up in water bodies (Deletic & Wang, 2019; Azizullah, 2011).
3. **Improving wastewater treatment:** Proper treatment of wastewater is critical in reducing water pollution. Sustainable development practices encourage the construction and maintenance of wastewater treatment plants, which help to remove contaminants from wastewater before it is released into water bodies (Nyaupane & Thapa, 2006; Rana, 2011).
4. **Promoting education and awareness:** Sustainable development involves educating the public on the need for responsible water use and management. By promoting awareness campaigns and educational programs, sustainable development can help to change behavior and attitudes towards water pollution, leading to more sustainable practices (Manasa & Mehta, 2020; Chen et al., 2020).

1.4. Objectives of the present research

The objective of sustainable development on water pollution is to promote the preservation and responsible use of water resources while preventing or reducing the negative impact of human accomplishments on marine quality. Some specific objectives of sustainable development on water pollution include.

- To reduce the amount of pollution entering water bodies. Sustainable development aims to minimize the amount of pollution that enters water bodies through industrial and domestic wastewater, agricultural runoff, and other sources. This objective involves promoting sustainable practices such as water conservation, proper waste management, and responsible use of pesticides and fertilizers.
- To preserve water quality and ecosystem health. Sustainable development seeks to maintain the quality of water resources and protect the health of aquatic ecosystems. This objective involves implementing measures to promote sustainable agricultural practices, and ensuring that wastewater is treated before being discharged into water bodies.
- To promote equitable access to clean water. Sustainable development aims to safeguard clean water access. This objective involves implementing measures to improve water supply and sanitation services in communities. It also promotes water conservation and its efficient use.
- To encourage innovation and collaboration. Sustainable development seeks to encourage innovation and collaboration to address water pollution challenges. This objective involves promoting research and development of new technologies and approaches to reduce water pollution, fostering partnerships among different stakeholders, and promoting knowledge sharing and best practices.

In summary, the objective of sustainable development is to promote responsible use of water resources, reduce pollution entering water bodies, preserve water quality and ecosystem health, promote equitable access to clean water, encourage innovation and collaboration, and ultimately achieve sustainable development goals related to water resources.

2. Literature Review

Water pollution is a major threat to sustainable development, and the literature has emphasized the importance of sustainable practices to address the issue. Vijay et al. (2011) investigated the influence of urbanization on water contamination in India and recommended sustainable growth practices such as promoting green infrastructure, improving wastewater treatment and management, and promoting sustainable urban planning to reduce water pollution and achieve sustainable development

goals. Liu et al. (2020) reviewed the literature on water pollution and sustainable development and emphasized the importance of promoting sustainable practices in the agricultural sector, reducing plastic waste, and improving wastewater treatment and management. The study also recommended increasing public awareness and education on the impacts of water pollution and promoting community involvement in sustainable water management.

Duttagupta et al. (2020) highlighted the need for sustainable development practices to address water pollution in India. The study recommended promoting sustainable agriculture practices, reducing industrial pollution, and improving wastewater treatment and management to achieve sustainable development goals related to water resources. Similarly, Jalil (2010) examined the effect of industrial pollution on water quality in Malaysia and recommended sustainable development practices such as implementing cleaner production processes, reducing water consumption, and promoting reuse and recycling of industrial waste to reduce water pollution and achieve sustainable development goals. Finally, Dwivedi (2017) studied the impact of agricultural runoff on water quality in India and recommended sustainable development practices such as promoting organic farming, reducing the use of biochemical manures and insecticides, and improving soil health to reduce agricultural pollution and achieve sustainable development goals related to water resources.

2.1. Promoting public awareness in sustainable water management

The literature on water pollution and sustainable development has highlighted the need for sustainable practices in agriculture, industry, and urban planning to reduce water pollution and achieve sustainable development goals related to water resources (Giri & Qiu, 2016; Smith & Siciliano, 2015). Promoting public awareness and education and involving communities in sustainable water management are also essential for addressing the issue of water pollution. Deletic and Wang (2019) inspected the effect of industrial wastewater discharge on water quality in China. The study recommended sustainable development practices such as implementing stricter regulations on industrial wastewater discharge, improving wastewater treatment and management, and promoting the use of clean production technologies to reduce water pollution and achieve sustainable development goals related to water resources.

Azizullah et al. (2011) considered an agricultural activity on water quality in Pakistan. The study recommended sustainable development practices such as promoting organic farming and improving soil health to reduce agricultural pollution and achieve sustainable development goals related to water resources. Nyaupane and Thapa (2006) inspected the influence of tourism on water pollution in Nepal. The study recommended sustainable development practices such as promoting sustainable tourism practices, improving wastewater treatment and management, and increasing public awareness and education to reduce water pollution and achieve sustainable development goals. Rana (2011) considered a case study on water quality in Bangladesh. The study recommended sustainable development practices such as promoting sustainable urban planning, improving wastewater treatment and management, and increasing public awareness and education to reduce water pollution and achieve sustainable development goals.

These studies demonstrate the prominence of ecological development practices in addressing the issue of water pollution and achieving sustainable development goals related to water resources. These practices include promoting clean production processes, reducing water consumption, improving wastewater treatment and management, and increasing public awareness and education on the impacts of water pollution.

2.2. Past literatures addressing the effects of water pollution

One study by Wang and Yang (2016) identified the discharge of industrial effluent as a significant cause of water pollution in China. The study found that the discharge of untreated or inadequately treated wastewater from industrial activities can lead to contamination of water bodies and negative impacts on aquatic ecosystems and human health. Chakraborty et al. (2021) identified mining activities as a significant cause of water pollution in India. The study found that the discharge of mine tailings and wastewater can lead to contamination of water bodies, affecting both social wellbeing and the environment. Khan et al. (2018) identified agriculture and livestock farming as major sources of nutrients and pollutants in surface and groundwater. The study found that the use of fertilizers and manure in agriculture and livestock farming can lead to eutrophication and contamination of water bodies, affecting the marine ecosystem. Xu et al. (2018) identified transportation activities, specifically the use of road salt during winter, as a significant cause of water pollution in urban areas. The study found that the use of road salt can lead to the release of chloride and other pollutants into surface and groundwater, posing a threat to aquatic ecosystems and human health. These studies focus on the assorted range of aspects that contribute to water pollution and demonstrate the need for multifaceted approaches to address this complex issue.

Sharma and Chatterjee (2017) explored the impact of micro plastics on marine organisms and ecosystems. The study found that micro plastics can cause physical harm to marine organisms, disrupt ecological processes, and transfer harmful chemicals into the food chain. Halder and Islam (2015) identified several negative impacts of water effluence on social health, including the spread of waterborne diseases, skin problems, and cancer. The study found that exposure to contaminated water can lead to a range of health issues, particularly in developing countries where admittance to clean water is limited. Prüss-Ustün et al. (2019) identified the economic impacts of water pollution, including costs associated with healthcare,

lost productivity, and damage to infrastructure. The study found that water pollution can lead to significant economic losses, particularly in developing countries where the burden of water-related diseases is highest. Whitehead et al. (2015) explored the impact of water pollution on aquatic ecosystems. The study found that water pollution can lead to reduced biodiversity, altered ecological processes, and negative impacts on fish populations and other aquatic organisms. These impacts can have far-reaching consequences for ecosystem services and anthropological well-being. These studies highlight the diverse range of negative impacts associated with water pollution, including effects on human health, aquatic ecosystems, and the economy, and emphasize the urgent need for effective water pollution control measures.

2.3. Past literatures addressing the preventive measures against water pollution

Tchobanoglous et al. (2003) identified a range of water pollution control technologies and management practices that can be used to mitigate the negative impacts of water pollution. These included source control measures (such as reducing pollution at its source), treatment technologies (such as wastewater treatment plants), and land management practices (such as riparian buffer zones). Babatunde et al. (2008) explored the use of constructed wetlands as a potential solution to water pollution. The study found that constructed wetlands can be an effective way to remove pollutants from water, including nutrients, heavy metals, and organic compounds. The study also highlighted the potential for constructed wetlands to provide other ecosystem services, such as habitat for wildlife and recreational opportunities. Ahmed et al. (2014) explored the potential for using nanotechnology to treat water pollution. The study found that nanomaterials can be used to remove a range of pollutants from water, including heavy metals, organic compounds, and micro plastics. The study also identified some of the challenges associated with using nanotechnology for water treatment, such as the potential for unintended consequences and the need for further research on the long-term impacts of nanomaterials. Coggins and Rosato (2002) explored the potential for using market-based mechanisms, such as pollution taxes and trading programs, to incentivize pollution reduction and improve water quality. The study found that market-based mechanisms can be an effective way to reduce pollution at a lower cost than traditional command-and-control regulations. These studies highlight a range of potential solutions to water pollution, including source control measures, treatment technologies, land management practices, constructed wetlands, nanotechnology, and market-based mechanisms.

2.4. Research gaps and novelty of present work

Water pollution and sustainable development are two critical areas of research that have gained significant attention in recent years due to the growing global concern over the sustainability of natural resources. However, despite the abundance of literature on these topics, there still exists a significant gap in understanding the relationship between water pollution and sustainable development. Therefore, a novel aspect of this research could be to investigate the impact of water pollution on sustainable development and identify potential solutions to address this issue.

While there has been significant research on water pollution and sustainable development, there remains a significant gap in understanding the linkages between these two critical areas. Many studies have focused on the impacts of water pollution on the environment and human health, but few have examined its implications for sustainable development. Moreover, there is a lack of research on how to integrate sustainable development goals into water pollution control policies and practices. This gap in knowledge presents a significant challenge for policymakers and practitioners seeking to develop effective strategies for managing water pollution while promoting sustainable development. Therefore, there is a need for further research to explore these issues and develop solutions that can contribute in achieving the sustainability goals.

3. Sources of water pollution

There are many sources which can cause water pollution (Giri & Qiu, 2016; Smith & Siciliano, 2015). The authors have identified some of the potential sources that may highly contaminate the water bodies and causes water pollution.

- i. **Industrial Waste:** Industries generate a significant amount of waste, including toxic chemicals and other pollutants, which are often dumped straight into nearby river bodies, leading to water pollution.
- ii. **Municipal Waste:** Poor waste management practices in urban areas can result in untreated sewage and other solid waste being dumped into water bodies, leading to pollution.
- iii. **Oil Spills:** Accidental oil spills from tankers or offshore drilling platforms can cause significant water pollution, leading to long-term environmental damage.
- iv. **Mining Activities:** Mining activities can contribute to water pollution by releasing heavy metals and other toxic substances into water bodies, contaminating them.
- v. **Plastic Pollution:** The widespread use of plastic products has resulted in significant plastic pollution in water bodies, leading to harm to aquatic life and human health.
- vi. **Atmospheric deposition:** Pollutants from the atmosphere, such as nitrogen and sulfur oxides, can be deposited in water bodies through rain or snow, leading to water pollution.
- vii. **Natural Causes:** Natural causes, such as algal blooms or volcanic eruptions, can also contribute to water pollution by releasing pollutants into water bodies.

- viii. **Illegal Dumping:** Illegal dumping of waste, such as construction debris or hazardous waste, can lead to water pollution.
- ix. **Leakage from Sewage Systems:** Aging sewage systems can sometimes leak, leading to the release of raw sewage into water bodies, contributing to water pollution.
- x. **Land Use Activities:** Land use activities, such as deforestation or urbanization, can lead to earth destruction and sedimentation in water bodies, which can reduce water quality and lead to pollution.
- xi. **Inadequate Infrastructure:** Inadequate infrastructure, such as wastewater treatment plants or solid waste management facilities, can contribute to water pollution by allowing untreated waste to enter water bodies.

These and other factors contribute to water pollution and pose significant challenges to achieving sustainable development goals related to water quality and access to clean water (Manasa & Mehta, 2020; Chen et al., 2020). Addressing these causes of water pollution will require a comprehensive and coordinated effort by policymakers, industries, and communities to ensure the ecological management of water resources.

4. Potential threats caused by water pollution

The effects of water pollution can be significant and far-reaching. There are several negative effects of water pollution on sustainable development (Alcamo, 2019; Zalidis, 2002). Some of the most notable effects of water contamination can be described as follows.

- i. **Damage to ecosystems:** Water pollution can have devastating effects on aquatic ecosystems, causing harm to fish, shellfish, and other aquatic species, and disrupting entire food chains and ecosystems (Belayutham, 2016).
- ii. **Economic impacts:** Water pollution can have significant economic impacts, including damage to fisheries and aquaculture, loss of tourism revenue, and increased costs of water treatment and cleanup. Water pollution can lead to economic costs in the form of lost income, reduced tourism, and increased healthcare costs. These costs can be significant and can negatively impact sustainable development (Swinton, 1999; Price, 2015).
- iii. **Water scarcity:** Water pollution can reduce the availability of clean water for human use, contributing to water scarcity and making it more difficult to achieve sustainable development goals related to water access and sanitation. This can lead to water scarcity, which can have negative impacts on sustainable development, particularly in regions where water resources are already limited (Vijay et al., 2011).
- iv. **Climate change:** Water pollution can exacerbate the impacts of climate change, leading to increased temperatures, acidification, and other changes in water chemistry that can have further negative effects on aquatic ecosystems and human health. It can also lead to health risks, environmental degradation and economic costs (Nyaupane and Thapa, 2006; Rana, 2011).
- v. **Loss of biodiversity:** Water pollution can lead to the loss of biodiversity in aquatic ecosystems, reducing the number of species and disrupting the balance of the ecosystem (Lacey-Barnacle et al., 2020).
- vi. **Groundwater contamination:** Water pollution can also contaminate groundwater, which is a vital source of drinking water for many communities. Contaminated groundwater can lead to health problems and make it more difficult and expensive to provide clean water to affected communities (Omer and Noguchi, 2020).
- vii. **Soil contamination:** Water pollution can also lead to soil contamination, reducing soil fertility and impacting agricultural productivity (Jalil, 2010; Dwivedi, 2017).
- viii. **Social impacts:** Water pollution can also have social impacts, as communities that rely on contaminated water sources may suffer from poverty, poor health, and reduced quality of life. This can lead to social unrest and conflict, which can hinder sustainable development (Goswami et al., 2022).
- ix. **Political instability:** Water pollution can contribute to political instability, as communities and countries may compete for scarce water resources, leading to conflicts and tensions (Kalpande and Toke, 2021; Price, 2015).
- x. **Food security:** Water pollution can affect food security by reducing the productivity of fisheries and agriculture. This can have serious consequences for sustainable development, as food security is a key element of poverty reduction and economic development (Deletic and Wang, 2019; Azizullah, 2011).
- xi. **Damage to infrastructure:** Water pollution can damage infrastructure, such as pipelines, water treatment plants, and irrigation systems. This can lead to increased maintenance and repair costs, which can have negative economic impacts and reduce the availability of essential services (Duttgupta et al., 2020).
- xii. **Loss of cultural heritage:** Water pollution can have negative impacts on cultural heritage, such as traditional fishing practices, cultural sites, and spiritual practices that are associated with water resources. This can lead to the loss of cultural identity and undermine sustainable development efforts that seek to promote cultural diversity and protect cultural heritage (Liu et al., 2020).
- xiii. **Inequitable distribution:** Water pollution can have a disproportionate impact on relegated and vulnerable populations, such as low-income communities and indigenous peoples. This can exacerbate existing inequalities and hinder sustainable development efforts that seek to promote social justice and reduce poverty (Swinton, 1999).

Therefore, water pollution can have significant negative impacts on sustainable development, affecting human health, environmental quality, economic prosperity, and social well-being. It is important to implement measures to prevent and mitigate water pollution to ensure sustainable development for current and future generations.

5. Remedies of water pollution

Handling the adverse issues related to water pollution can be critical and difficult. Some preventive measures and comprehensive approaches are required to deal with this matter. Here are some remedies for water pollution.

- i. **Reduce industrial pollution:** Governments and industries can work together to reduce industrial pollution by promoting the use of cleaner technologies, regulations should be implemented by encouraging the recycling and safe disposal of hazardous waste (Coggins & Rosato, 2002).
- ii. **Promote sustainable agriculture:** Governments and farmers can work together to promote the use of natural pest control methods, and implementing conservation practices that reduce soil erosion and sedimentation in water bodies (Ahmed et al., 2014).
- iii. **Improve municipal waste management:** Municipalities can invest in modern waste management systems, such as wastewater treatment plants and solid waste management facilities, to ensure that untreated waste is not discharged into water bodies (Babatunde et al., 2008).
- iv. **Reduce plastic pollution:** Governments and communities can work together to prevent plastic waste from entering water bodies (Tchobanoglous et al., 2003).
- v. **Protect and restore ecosystems:** Governments and conservation organizations can work together to protect and restore ecosystems that have been impacted by water pollution. This can involve restoring wetlands and other natural habitats, reducing nutrient pollution, and implementing programs that promote biodiversity conservation (Giri & Qiu, 2016; Smith & Siciliano, 2015).
- vi. **Implement water quality monitoring:** Governments and communities can work together to implement effective water quality monitoring programs that provide timely and accurate information about water quality (Azizullah et al., 2011).
- vii. **Educate and engage communities:** This can involve public awareness campaigns, community outreach programs, and educational programs in schools and universities (Dwivedi, 2017).
- viii. **Implement source water protection:** This can involve implementing best management practices on farms and in other land use activities, regulating activities near water sources, and promoting sustainable land use practices (Jalil, 2010).
- ix. **Use natural infrastructure:** Natural infrastructure, such as wetlands and forests, can be used to filter pollutants and protect water quality. Governments and communities can invest in the protection and restoration of natural infrastructure to promote sustainable water management (Rana, 2011).
- x. **Encourage public participation:** Encouraging public participation in decision-making processes related to water management can help ensure that local perspectives are taken into account and can build support for efforts to reduce water pollution. This can involve public hearings, public comment periods, and other forms of public engagement (Sahoo and Choudhury, 2022).
- xi. **Support research and innovation:** Governments and industry can support research and development of new technologies and can provide funding for research on effective policy and regulatory approaches (Halder and Islam, 2015; Tran, 2002).

So, the following initiatives may be implemented by investing on clean technologies. By working together, governments, industry, and communities can ensure the long-term health and sustainability of water resources.

6. Role of sustainability in minimizing the risk of water pollution

Water pollution is a serious environmental issue that can have significant impacts on human health and the natural environment. Here are some ways in which sustainable development can be achieved in relation to water pollution.

- i. **Reduce pollution at the source:** The most effective way to prevent water pollution is to reduce the amount of pollution at the source. This can be achieved using cleaner production technologies, reducing waste and emissions, and using more sustainable and environmentally friendly products (Price, 2015).
- ii. **Proper management of wastewater:** Proper treatment and management of wastewater can prevent pollution of water bodies. It is important to ensure that wastewater is treated before it is released into the environment, and that it meets the necessary standards (Kalpande & Toke, 2021; Price, 2015).
- iii. **Implement water conservation measures:** Conserving water can help reduce pollution by reducing the amount of wastewater that needs to be treated that can be achieved by improving irrigation efficiency, and using rainwater harvesting techniques (Zalidis, 2002; Belayutham, 2016).

6.1. Positive impact of sustainable development on ecosystem

There are several positive effects of sustainable development that helps to preserve biodiversity and maintain a balanced ecosystem. Sustainable development can help to mitigate the environmental effects of water pollution by promoting environmentally responsible practices and policies that reduce the amount of pollution entering our water systems (Alcamo, 2019). Sustainable development has numerous environmental effects and impacts that can help to mitigate climate change, reduce pollution, and preserve natural resources. Some of the key environmental effects and positive impacts of sustainable development include.

- i. **Improved water quality:** Sustainable development measures can help improve water quality by reducing pollution at the source, promoting better wastewater management practices, and encouraging sustainable agricultural practices. This can lead to cleaner and healthier water resources, which can support human health, ecological diversity, and sustainable economic development (Ahmed et al., 2014).
- ii. **Increased access to clean water:** Sustainable development measures can increase access to clean water resources, particularly for marginalized and vulnerable populations (Whitehead et al., 2015).
- iii. **Reduced greenhouse gas emissions:** Sustainable development measures can help reduce greenhouse gas emissions associated with water pollution, such as those from wastewater treatment and agriculture (Prüss-Ustün et al., 2019).
- iv. **Improved ecosystem services:** Sustainable development measures can improve the health and resilience of aquatic ecosystems. This can support sustainable economic development, particularly in sectors such as fisheries, tourism, and agriculture (Davies and Mazumder, 2003; Laudon, 2016).
- v. **Innovation and entrepreneurship:** Sustainable development measures can foster innovation and entrepreneurship in the water sector, particularly in areas such as water treatment, conservation, and management. This can support economic development, job creation, and social well-being, particularly in regions where water resources are limited (Sharma and Chatterjee, 2017).
- vi. **Increased water efficiency:** Sustainable development measures can increase water efficiency in industrial, agricultural, and urban sectors, reducing water waste and increasing water availability. This can support sustainable economic development and reduce the negative impacts of water scarcity (Xu et al., 2018).
- vii. **Improved governance:** Sustainable development measures can promote improved water governance, including stronger laws and regulations, better stakeholder engagement, and more transparent decision-making processes. This can support sustainable economic development, reduce conflict and promote social justice, particularly in regions where water resources are contested (Wang and Yang, 2016).
- viii. **Enhanced public health:** Sustainable development measures can enhance public health by reducing exposure to waterborne diseases and improving access to clean water. This can support sustainable economic development by reducing healthcare costs and increasing productivity (Khan et al., 2018).
- ix. **Increased community engagement:** Sustainable development measures can increase community engagement in water management, including the participation of women, youth, and marginalized groups (Chakraborty et al., 2021).
- x. **Conservation of natural resources:** Sustainable development emphasizes the importance of conservation and sustainable use of natural resources such as water, land, and forests, which can help to protect ecosystems and biodiversity (Deletic and Wang, 2019; Azizullah, 2011).
- xi. **Waste reduction and recycling:** Sustainable development promotes waste reduction and recycling practices, which can help to reduce the environmental impacts of waste disposal (Liu et al., 2020).
- xii. **Improved air quality:** Sustainable development encourages the use of cleaner energy sources and transportation systems (Liu et al., 2020; Dutttagupta et al., 2020).

So, sustainable development can have a range of positive effects on water pollution, including improved water quality, increased access to clean water, reduced greenhouse gas emissions, improved ecosystem services, and increased innovation and entrepreneurship (Reddy and Behera, 2006). Moreover, sustainable development has a positive impact on the environment by promoting environmentally responsible practices and policies that reduce pollution, mitigate climate change, and protect natural resources. These positive effects can support sustainable economic development, social well-being, and environmental sustainability.

6.2. Impact of sustainable development on Indian economy

Water pollution can have significant economic impacts, both in terms of the costs of pollution prevention and mitigation and the economic opportunities that can be lost due to degraded water resources. On the other hand, sustainable development measures can also have economic effects on water pollution, including:

- i. **Reduced costs of pollution:** Sustainable development measures can help reduce the costs of water pollution, such as those associated with treatment of contaminated water, health care costs, and impacts on fisheries and agriculture. By reducing pollution at the source, sustainable development measures can help avoid or minimize these costs (Giri & Qiu, 2016).
- ii. **Increased economic opportunities:** Sustainable development measures can create new economic opportunities, particularly in sectors such as eco-tourism, sustainable agriculture, and water treatment technologies. This can support economic growth and job creation, particularly in regions where water resources are abundant but underutilized (Smith & Siciliano, 2015).
- iii. **Improved efficiency:** Sustainable development measures can improve the efficiency of water use in industries, agriculture, and urban areas, reducing waste and increasing productivity. This can support economic development and reduce the negative impacts of water scarcity (Babatunde et al., 2008).
- iv. **Enhanced competitiveness:** Sustainable development measures can enhance the competitiveness of businesses and industries by promoting sustainable practices and reducing the risks associated with water pollution. This can

support economic development and job creation, particularly in sectors such as manufacturing and agriculture (Reddy & Behera, 2006).

- v. **Increased investment:** Sustainable development measures can attract investment that supports economic growth and job creation, particularly in regions where water resources are limited or vulnerable to climate change (Prüss-Ustün et al., 2019).
- vi. **Improved water pricing:** Sustainable development measures can promote improved water pricing mechanisms, such as user fees, water tariffs, and water markets, which can help ensure that water resources are used efficiently and sustainably (Xu et al., 2018).
- vii. **Reduced trade barriers:** Sustainable development measures can help reduce trade barriers related to water pollution, such as non-tariff barriers to trade in fish and seafood. This can support economic growth by increasing trade and expanding markets for sustainable products and services (Khan et al., 2018).
- viii. **Enhanced resource management:** Sustainable development measures can promote better resource management practices, such as water conservation, land-use planning, and ecosystem-based approaches to water management. This can support sustainable economic development by ensuring that water resources are used efficiently and sustainably (Chakraborty et al., 2021).
- ix. **Improved access to financing:** Sustainable development measures can improve access to financing for water-related projects, such as water treatment plants, irrigation systems, and watershed management projects. This can support economic development and job creation, particularly in regions where water resources are limited or vulnerable to climate change (Tchobanoglous et al., 2003).

Sustainable development can have a range of economic effects on water pollution, including reduced costs, increased economic opportunities, improved efficiency, enhanced competitiveness, attracting investment, improved water pricing, reduced trade barriers, increased resilience, enhanced resource management, and improved access to financing (Ahmed et al., 2014). These economic effects can support sustainable economic development and reduce the negative impacts of water pollution on economic growth and job creation. Although sustainable development is not directly related to the economic factors, but indirectly it highly influence the country's economic and financial aspects which is evident from the mentioned points.

6.3. Impact of sustainable development on climate change

Climate change can have significant effects on water resources, including amplified occurrence and intensity of floods and droughts, changes in precipitation patterns, and sea level rise. These impacts can exacerbate water pollution and make it more difficult to manage and protect water resources (Lam and Li, 2019). Climate change is one of the important aspects that shouldn't be overlooked, because in last few years we have noticed significant rise in the earth's average temperature. Pollution is one of the primary causes behind global warming. If these things continue to happen then it would be very difficult for our future generation to survive. However, sustainable development measures can help reduce the impacts of climate change on water pollution, including.

- i. **Mitigation of greenhouse gas emissions:** Sustainable development measures help to mitigate greenhouse gas emissions from sources such as energy production, transportation, and agriculture (Alcamo, 2019).
- ii. **Adaptation to climate change:** Sustainable development measures can help communities to improve water management practices, increased use of water-efficient technologies, and the development of climate-resilient infrastructure (Omer & Noguchi, 2020).
- iii. **Protection of ecosystems:** Sustainable development measures can help protect ecosystems that play important roles in regulating water quality, such as wetlands, forests, and coral reefs (Lacey-Barnacle et al., 2020).
- iv. **Innovation and entrepreneurship:** Sustainable development measures can promote innovation and entrepreneurship in water-related sectors, such as water treatment technologies and sustainable agriculture. By promoting the development of new technologies and business models, sustainable development can help address the challenges posed by climate change and water pollution while creating economic opportunities (Davies and Mazumder, 2003; Laudon, 2016).
- v. **Increased stakeholder engagement:** Sustainable development measures can increase stakeholder engagement in water management, including the participation of women, youth, and marginalized groups. By engaging a diverse range of stakeholders, sustainable development can help ensure that water management decisions are inclusive and take into account the needs and perspectives of all members of the community (Lam & Li, 2019).

7. Conclusions

In conclusion, sustainable development plays a crucial role in reducing water pollution. Sustainable development approaches aim to endorse financial growth, social progress, and environmental protection in a balanced and integrated manner. By adopting sustainable practices, such as decreasing the usage of harmful chemicals, managing waste properly, and promoting responsible water usage, we can reduce the amount of pollutants that enter our waterways. Additionally, sustainable development approaches can also help promote the conservation and restoration of ecosystems that play a critical role in maintaining water quality. For example, wetlands and other natural habitats can act as ordinary filters, eliminating con-

taminants from water before it enters our rivers and streams. Sustainable development is essential to reducing water pollution and protecting the health and wellbeing of our communities and the environment. By taking a comprehensive and integrated approach to economic, social, and ecological challenges, we can create a more sustainable future for generations to come.

7.1. Practical implications

The practical implications of sustainable development in reducing water pollution are vast and varied. Here are some few examples that highlight the applicability of this research in practical life.

- **Implementing responsible water usage practices:** Sustainable development practices can promote responsible water usage by individuals, businesses, and communities. This can include reducing water waste, improving water management practices, and promoting water conservation efforts.
- **Managing waste properly:** Improper waste management is a significant contributor to water pollution. Sustainable development practices can help promote proper waste management, including recycling, composting, and responsible disposal of hazardous waste.
- **Promoting the use of eco-friendly products:** Many household and industrial products contain harmful chemicals that can pollute our waterways. Sustainable development approaches can promote the use of eco-friendly products, reducing the amount of pollutants that enter our water systems.
- **Protecting and restoring natural habitats:** Ecosystems, such as wetlands and forests, play a critical role in maintaining water quality by acting as natural filters. Sustainable development practices can promote the conservation and restoration of these habitats, helping to improve water quality.

The practical implications of sustainable development in reducing water pollution involve a comprehensive and integrated approach to economic, social, and environmental challenges. By adopting sustainable practices, we can reduce the amount of pollutants that enter our water systems, protect our environment, and promote the health and wellbeing of our communities.

7.2. Limitations

Despite its many benefits, sustainable development has several limitations when it comes to reducing water pollution. Here are a few points that depicts some of the limitations in achieving the proper sustainable development.

- **Lack of political will:** Sustainable development often requires significant changes in policy and governance. However, policymakers may lack the political will to implement necessary changes, such as regulations to reduce water pollution from industries.
- **Limited resources:** Implementing sustainable development practices can be costly, making it challenging for many individuals, businesses, and communities to adopt them fully.
- **Limited public awareness:** Many people are still unaware of the importance of sustainable development practices and their role in reducing water pollution. Without public awareness, there may be limited support for sustainable development initiatives.
- **Conflicting priorities:** Sustainable development can involve balancing economic, social, and environmental priorities. This can make it challenging to prioritize efforts to reduce water pollution over other priorities such as economic growth.
- **Climate change:** Climate change can affect the effectiveness of sustainable development approaches to reduce water pollution.

Sustainable development is an important approach to reducing water pollution. However, it is essential to recognize and address its limitations to ensure its effectiveness in achieving sustainable and healthy ecosystems.

7.3. Future scope

The scope of future work of sustainable development in reducing water pollution is vast, and there are many areas where we can focus our efforts.

- **Strengthening regulations and policies:** Sustainable development practices require supportive policies and regulations to promote responsible water usage and reduce water pollution. Future work can focus on strengthening existing regulations and policies and developing new ones where necessary.
- **Encouraging innovation and technology development:** The development of new and innovative technologies can help reduce water pollution by improving water treatment processes, reducing the use of harmful chemicals, and improving waste management practices. Future work can focus on encouraging innovation and technology development to support sustainable development practices.

- **Promoting public awareness:** Public awareness is essential to drive sustainable development practices that reduce water pollution. Future work can focus on promoting public awareness of the importance of sustainable development practices, their benefits, and their impact on water quality.

The scope of future work of sustainable development in reducing water pollution involves a comprehensive and integrated approach that includes policy, technology, public awareness, international cooperation, and collaboration among stakeholders. With a concerted effort, we can create a more ecological future for generations to come, with clean and healthy water systems that support life and wellbeing.

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