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Drowning in Contamination: The Hidden Perils and Solutions to Water Pollution in Nepal

Aswasthama Bhakta Kharel, PhD
Assistant Professor, Department of Political Science,
Ratna Rajyalaxmi Campus, Tribhuvan University
ORCID: https://orcid.org/0009-0009-9203-4040

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Corresponding Authors:

aswasthma.kharel@gmail.com

Abstract

Water pollution in Nepal has emerged as a critical environmental and public health issue, driven by rapid industrialization, agricultural intensification, and unregulated urban expansion. This research analyzes the multifaceted problem of water pollution in Nepal, aiming to identify key pollution sources, evaluate their impacts, and propose actionable mitigation strategies. Employing a qualitative approach, the study relies on secondary data from government reports, academic literature, and reputable environmental organizations to provide a thorough analysis. The research identifies industrial discharge, agricultural runoff, and untreated domestic sewage as the primary contributors to water pollution. The consequences extend beyond environmental degradation, profoundly affecting human health through the proliferation of waterborne diseases, diminishing biodiversity, and disrupting aquatic ecosystems. Particularly, communities depending on contaminated water sources face significant socio-economic hardships, including health risks and loss of livelihood, highlighting the urgent need for effective intervention. The study emphasizes the necessity of a multi-pronged mitigation approach, advocating for enhanced regulatory frameworks, public education, and sustainable agricultural practices. It also highlights the potential benefits of advanced wastewater treatment technologies and community-driven water conservation initiatives. The findings reflect the immediate need for integrated policy reforms and grassroots engagement to combat water pollution, supporting Nepal's broader goals of environmental sustainability and improved public health.

Introduction

Water pollution poses a critical threat to public health, ecosystems, and socio-economic development, and this issue is particularly acute in Nepal. Despite its reputation for abundant water resources and significant river systems originating from the Himalayas, Nepal struggles with maintaining water quality amid escalating pollution levels. These water bodies, essential for agriculture, drinking water, and hydropower, face substantial contamination from rapid urbanization, industrial activities, and population growth. This contamination stems primarily from industrial discharges, agricultural runoff containing pesticides and fertilizers, and untreated sewage, leading to the degradation of rivers, lakes, and groundwater systems. The adverse consequences include a surge in waterborne diseases like cholera and dysentery, severe biodiversity loss, and the disruption of aquatic habitats, disproportionately affecting vulnerable communities reliant on these polluted water sources for their livelihoods, furthering cycles of poverty and ill-health (Balkhi et al., 2023; Bhandari et al., 2021).

Given the criticality of this issue, this study seeks to address three central questions: What are the primary sources of water pollution in Nepal? What are the impacts of these pollutants on human health, ecosystems, and socio-economic conditions? And which mitigation strategies could be implemented effectively to address water pollution? These questions guide the study's objectives, which are to identify and analyze water pollution sources, evaluate their environmental and health impacts, and propose actionable mitigation strategies. This research adopts a qualitative approach, utilizing secondary data from government reports, academic studies, and NGOs to develop a nuanced understanding of Nepal's water pollution crisis. By synthesizing data from these credible sources, the study seeks to provide actionable insights that can guide policy decisions and community initiatives focused on sustainable water management and public health (Giri et al., 2022; Chapagain et al., 2020; Bhattarai & Dahal, 2020). The findings emphasize the urgency of addressing Nepal's water pollution through a comprehensive, multi-level approach, encompassing regulatory enhancements, public awareness initiatives, and sustainable agricultural practices. This research aims to bridge existing gaps in literature by focusing on the socio-economic ramifications of water pollution, particularly on marginalized communities, and highlighting potential strategies for sustainable water management. In doing so, this study aspires to contribute to Nepal's broader efforts toward environmental sustainability and public health.

Water pollution in Nepal is a pressing challenge with significant implications for public health, environmental sustainability, and socio-economic stability. Several studies have documented the declining water quality across Nepal’s major rivers, lakes, and groundwater sources, highlighting the influence of rapid urbanization, industrial expansion, and increased agricultural activity on this issue. Research by Balkhi et al. (2023) provides a broad assessment of water quality concerns in Nepal, identifying industrial discharge, agricultural runoff, and insufficient sewage treatment as key contributors to water pollution. The need for robust water management practices to protect these essential resources is central to their findings.

A prominent case of water pollution is seen in the Bagmati River, which flows through Kathmandu Valley. Studies by Bhandari et al. (2021) and Giri et al. (2022) reveal that untreated municipal sewage and industrial effluents are severely impacting the water quality, creating hazards for public health. These studies also observe elevated levels of heavy metals and organic pollutants, which jeopardize aquatic biodiversity and call for improved water quality monitoring and enforcement of environmental regulations. Industrial activities, particularly in the textile, chemical, and food processing sectors, significantly contribute to water pollution through the release of untreated waste. Chapagain et al. (2020) utilized an extended input-output model to assess how manufacturing practices affect water quality, emphasizing the urgent need for stricter pollution controls and cleaner production technologies within these industries. Similarly, the excessive use of chemical fertilizers and pesticides in agriculture has led to widespread contamination of surface and groundwater sources, as noted by Bhattarai and Dahal (2020), with consequences such as algal blooms and habitat degradation.

The socio-economic impacts of water pollution are pronounced in communities dependent on polluted water for drinking, irrigation, and other uses. Gyawali et al. (2023) discuss how these communities face heightened health risks and economic challenges, particularly in rural areas where access to clean water is limited. Chauhan et al. (2023) highlight policy gaps that contribute to the degradation of rural spring water sources, stressing the need for targeted interventions to safeguard these critical resources. Additionally, Shrestha et al. (2023) underscore the importance of addressing water pollution as part of broader water, sanitation, and hygiene (WASH) initiatives, especially in rural settings where access to safe water is limited. Despite the extensive research on water pollution in Nepal, gaps remain. Few studies have comprehensively integrated the various pollution sources and their cumulative impacts on water quality across diverse regions of Nepal. Additionally, limited research has focused on the long-term socio-economic impacts of water pollution, particularly on vulnerable communities. There is also insufficient analysis on the efficacy of current mitigation strategies, including policy frameworks, technological interventions, and community-driven initiatives. This research aims to address these gaps through a holistic assessment of water pollution in Nepal, integrating data from varied sources to provide an in-depth understanding of the issue and its broader

impacts. By focusing on the socio-economic implications of water pollution, this study seeks to propose sustainable solutions that can guide future policy and community action.

Methods

This research adopts a qualitative approach, specifically a systematic qualitative research design, to thoroughly examine the water pollution situation in Nepal. This design is chosen to meet the study's objectives, which include identifying the main sources of pollution, assessing their health and environmental impacts, and proposing effective mitigation strategies. The study utilizes secondary data gathered from reputable sources, including governmental reports, peer-reviewed academic journals, and publications from recognized environmental organizations. By systematically analyzing these diverse data sources, the study constructs a comprehensive narrative of the current challenges in managing water pollution and its socio-economic implications. To ensure the quality and credibility of secondary sources, the study applies a rigorous source-selection process. Criteria for data inclusion focus on recent publications from reliable institutions and peer-reviewed research to maintain high standards of validity. Governmental reports are selected based on their recent publication dates and scope of coverage, ensuring the information reflects current conditions and official policy perspectives. Academic sources are chosen from reputable journals with high impact factors, while publications from environmental organizations are selected based on their established history of reliable reporting and advocacy.

The systematic analysis process is carried out by categorizing data into themes related to sources of pollution, impacts on health and ecosystems, and mitigation strategies. This approach has allowed for the distillation of complex information into cohesive narratives. A qualitative content analysis is conducted to interpret and synthesize findings, focusing on identifying patterns, gaps, and contradictions within the data. To enhance reliability, multiple rounds of cross-checking are performed, ensuring consistency in interpretation. To ensure reliability, each data source is critically evaluated for consistency with other sources, reducing the risk of bias. The study utilized triangulation by cross-verifying findings from different sources to ensure the data's robustness. For validity, data relevance and accuracy is confirmed by selecting sources directly addressing Nepal's water pollution issues, specifically those concerning the study's objectives. Where possible, information from secondary sources is compared to recent statistics and findings from primary reports to verify alignment and accuracy. Though based on secondary data, the study adheres to ethical guidelines by accurately citing all sources and giving due credit to original authors. The study avoids any misrepresentation or misinterpretation of the original data and respects intellectual property rights. Ethical considerations also include transparency in the selection of data sources and clarity in reporting limitations, thereby ensuring integrity and accountability in the research process.

Results

This study categorizes the sources, impacts, and mitigation strategies of water pollution in Nepal, systematically analyzing how they intersect with existing environmental, health, and socio-economic challenges. Using a thematic approach, the study examines both point and non-point sources of water pollution, assesses the impacts on public health and biodiversity, and evaluates the efficacy of current mitigation efforts, aligning the findings with empirical support from the literature.

Sources of Water Pollution

In Nepal, water pollution arises from both point and non-point sources, each uniquely contributing to widespread water degradation. Point sources—including industrial and municipal sources—are identifiable, localized contributors. Industrial facilities, such as those in textile production, paper manufacturing, and tanning, release inadequately treated wastewater rich in toxic chemicals, heavy metals, and organic pollutants directly into rivers. These discharges pose significant risks to aquatic ecosystems and public health, as they often bypass treatment protocols that could mitigate their toxicity (Goel, 2006; Chaudhry & Malik, 2017). The industrial effluents not only compromise water quality but are also linked to long-term health issues in communities relying on these water sources. Such findings echo Karn and Harada's (2001) study, which documented similar cases of untreated sewage from densely populated urban areas like Kathmandu Valley, increased by outdated infrastructure that funnels municipal waste directly into rivers. Bhattarai and Dahal (2020)

support this by highlighting how inadequate sewage systems significantly heighten waterborne disease risks.

In addition to point sources, non-point sources—such as agricultural runoff, deforestation, and unmanaged solid waste disposal—further intensify pollution. Agricultural runoff, especially in regions like Terai, introduces high levels of pesticides and chemical fertilizers into water bodies. This nutrient-rich runoff encourages harmful algal blooms that deplete oxygen levels in water, disrupt aquatic life, and contaminate drinking water sources, consistent with Singh and Gupta's (2016) findings. Duda (1993) underscores the environmental hazards of nutrient pollution, describing how excessive fertilizers impact the chemical balance of water, promoting algal blooms detrimental to aquatic ecosystems. Deforestation and the subsequent soil erosion also play critical roles in pollution. Erosion carries sediment and organic matter into rivers, smothering aquatic habitats and reducing water quality (Myers et al., 1985). This sedimentation not only degrades water clarity but also limits light penetration, hindering photosynthesis in aquatic plants and affecting the overall ecosystem. Furthermore, livestock waste in rural areas compounds pollution, with runoff from pastures adding to bacterial contamination and nutrient load in rivers and lakes. Chaudhry and Malik (2017) similarly observed rural water sources often impacted by agricultural and livestock practices, emphasizing the broader challenge of rural water management.

Climate change is another complicating factor. Climate-induced glacier melt and erratic rainfall patterns in Nepal increase pollutant runoff, making natural water purification processes less effective. Sarker et al. (2021) note that climate change accelerates these pollution issues, as unpredictable rainfall leads to more frequent, intense runoff events that overwhelm natural and engineered water treatment systems. This relationship between climate change and pollution exacerbates existing vulnerabilities, especially for communities directly dependent on rivers for agriculture, fishing, and drinking water. Collectively, these sources of water pollution demonstrate the complex, interconnected nature of the country's water pollution challenges. Industrial growth, urban expansion, agricultural practices, deforestation, and climate impacts converge to create a daunting pollution landscape

Impacts of Water Pollution

The impacts of water pollution in Nepal are profound, affecting human health, ecosystems, and socio-economic conditions in both urban and rural areas. Contaminated water poses serious health risks, leading to widespread cases of waterborne diseases such as cholera, dysentery, and typhoid fever (Lin et al., 2022). This is especially alarming in communities without access to purified water or adequate sanitation infrastructure, as Madhav et al. (2020) found that long-term exposure to polluted water not only leads to acute illnesses but also contributes to chronic health issues like gastrointestinal and skin diseases. The problem is intensified in regions with limited healthcare services, as these areas struggle to address the high incidence of these diseases, resulting in higher mortality and morbidity rates (Bhattarai & Dahal, 2020). Water pollution also has indirect health impacts by weakening immunity over time, making affected communities more susceptible to other diseases and further burdening already fragile healthcare systems.

Ecologically, water pollution introduces complex challenges by disrupting both aquatic biodiversity and the ecosystem services that support food chains and nutrient cycles. Industrial and agricultural pollutants, including toxic chemicals and heavy metals, harm fish, amphibians, and other aquatic life by accumulating in the food chain and interfering with reproduction, growth, and survival (Qadri & Faiq, 2020). This disruption of aquatic species also affects terrestrial animals and human populations that rely on these resources for food. Ogidi and Akpan (2022) and Morin-Crini et al. (2022) emphasize that pollution hampers essential ecological functions such as nutrient cycling and habitat formation, impacting not only individual species but also entire ecosystems. For example, pollutants contribute to eutrophication, depleting oxygen levels in water bodies and leading to "dead zones" where most aquatic life cannot survive. This degradation decreases ecosystem resilience, making them less capable of adapting to further environmental stressors such as climate change.

In socio-economic terms, the impacts are particularly severe in rural communities that depend on rivers, lakes, and groundwater for drinking water and irrigation. For many, polluted water sources directly threaten livelihoods by reducing agricultural productivity and fish populations. This loss of productivity worsens poverty cycles, as farmers and fishers experience diminished incomes and increased vulnerability to economic instability, a finding supported by Gyawali et al. (2023). Moreover, the financial burden of treating waterborne diseases is significant. Shrestha et al. (2023) observed that high healthcare costs for treatment of illnesses related to water contamination strain household finances, often forcing families into debt or depriving them of funds needed for education, food, and other essentials.

The impacts are disproportionately felt by marginalized and low-income populations, who lack access to alternative, safe water sources. Singh et al. (2020) highlights that these communities are often situated in areas with minimal infrastructure investment, further limiting their access to clean water and healthcare resources. This inequality perpetuates social and economic disadvantages, creating a vicious cycle where water pollution both results from and contributes to poverty and marginalization. These insights signify the need for comprehensive interventions that address not only water quality but also broader socio-economic conditions to reduce health risks and support community resilience in the face of pollution.

Current Mitigation Strategies

Nepal has enacted several legislative measures aimed at controlling water pollution, notably through the Environment Protection Act (EPA) and the Water Resources Act. These laws establish critical frameworks mandating that industries treat their wastewater prior to discharge into the environment. However, the effectiveness of these laws is undermined by weak enforcement mechanisms that enable industries to bypass regulations, leading to ongoing pollution issues (Bhandari et al., 2021). The problem is compounded by insufficient monitoring and accountability measures, as Bhattarai and Dahal (2020) emphasize that regulatory bodies often lack the resources and authority necessary to enforce compliance effectively. Moreover, existing legal frameworks inadequately address non-point sources of pollution, such as agricultural runoff, which presents significant challenges to comprehensive pollution management. This gap has been previously identified by Chaudhry and Malik (2017), who highlighted the need for targeted policies to mitigate pollution from agricultural practices, particularly in regions where chemical fertilizers and pesticides are heavily used. Without adequate regulations for non-point sources, efforts to improve water quality may remain limited, leaving many waterways vulnerable to contamination.

To bolster pollution mitigation, public awareness and environmental education campaigns are essential. These initiatives have shown promise in fostering community engagement and encouraging local populations to participate in pollution control efforts (Giri et al., 2022). However, the impact of these campaigns is often diluted in rural areas due to limited access to education and resources. Gyawali et al. (2023) note that in many rural communities, a lack of educational infrastructure impedes the efforts to promote sustainable practices and raise awareness about the importance of water quality. Enhancing environmental education at all levels—formal, informal, and vocational—could foster more effective, community-driven initiatives aimed at pollution reduction, as suggested by Shrestha et al. (2023). In addition to legislative and educational efforts, technological advancements offer promising solutions for pollution control. Innovative wastewater treatment technologies, such as membrane filtration and constructed wetlands, have demonstrated potential in effectively reducing pollutant loads in various contexts (Balkhi et al., 2023). However, the adoption of these technologies is often limited by their high costs and the technical expertise required for implementation, as Karki et al. (2023) have observed. This creates a significant barrier for many local governments and industries, particularly in low-income areas where funding for such technologies is scarce.

In the agricultural sector, the promotion of sustainable practices is crucial for reducing nutrient runoff and improving water quality. Approaches such as the use of bio-fertilizers and organic farming not only mitigate pollution but also enhance soil health and agricultural productivity, aligning with Duda's (1993) findings on sustainable farming. These practices contribute to long-term environmental and economic sustainability, as supported by Singh and Gupta (2016), who argue that

transitioning to more sustainable agricultural methods can alleviate some of the pressures on water resources. While Nepal has established a framework for addressing water pollution through legislation and community engagement, significant gaps remain in enforcement, education, and technological access. A multi-faceted approach that includes strengthening regulatory frameworks, enhancing public education, and promoting sustainable agricultural practices is essential for effectively combating water pollution and safeguarding the country's water resources for future generations. Addressing these challenges holistically will not only improve water quality but also enhance public health and ecological resilience across Nepal.

Discussion

Addressing water pollution in Nepal requires such an approach that not only strengthens existing policies but also actively involves communities and promotes the adoption of sustainable practices. Improving the regulatory frameworks governing water pollution is essential for achieving meaningful progress. Current laws, while comprehensive in scope, often fall short in terms of enforcement and coverage. Strengthening these frameworks involves revising existing regulations to address gaps, particularly in managing non-point source pollution like agricultural runoff. Additionally, enhancing the capacity of regulatory bodies is crucial. This could include providing adequate resources, training, and technical support to ensure that these agencies can effectively monitor and enforce compliance. Furthermore, there is a need for greater coordination between governmental and non-governmental organizations. Governmental bodies should work closely with NGOs that have a strong presence in local communities to implement water management programs that are both effective and sustainable. These collaborations can help bridge the gap between policy and practice, ensuring that regulatory measures are not only well-designed but also well-implemented.

Community involvement is vital in water management, particularly in rural and remote areas where governmental reach is limited. Empowering local communities to take charge of their water resources can lead to more sustainable and effective outcomes. Community-led initiatives can range from grassroots movements focused on preserving local water bodies to organized water management committees that oversee the equitable distribution and use of water resources. Case studies from various regions in Nepal have demonstrated the success of such initiatives. In several villages of Nepal, community groups have successfully implemented rainwater harvesting systems, reducing their reliance on polluted water sources and improving overall water security. These initiatives not only address water pollution but also build community resilience against environmental changes. By fostering a sense of ownership and responsibility among local populations, these programs ensure long-term sustainability and encourage the adoption of best practices in water conservation.

Promoting sustainable practices is another critical strategy in combating water pollution. In the agricultural sector, the adoption of organic farming techniques and sustainable irrigation methods can significantly reduce the amount of chemical runoff entering water bodies. These practices include the use of natural fertilizers, crop rotation, and drip irrigation, all of which minimize the environmental impact of farming. Incentivizing industries to adopt cleaner technologies is essential. Industries are major contributors to water pollution, and encouraging them to implement advanced wastewater treatment systems can drastically reduce the discharge of pollutants. Government incentives, such as tax breaks or subsidies for companies that invest in green technologies, can accelerate this transition. Public-private partnerships could be established to promote research and development in sustainable technologies, ensuring that industries have access to the tools they need to reduce their environmental footprint.

Conclusion

Water pollution in Nepal is a profound environmental and public health crisis with wide-ranging implications for the country's ecosystems, communities, and development trajectory. This research identifies complex, interlinked pollution drivers from industrial discharges, agricultural runoff, and untreated sewage to climate-driven changes each intensifying health risks, ecological damage, and socio-economic strain, particularly for vulnerable communities reliant on contaminated water sources. The prevalence of waterborne diseases like cholera and dysentery and the decline in biodiversity both underscore the urgent need to address these impacts. Despite efforts to mitigate

pollution, substantial obstacles persist, including lax regulatory enforcement, limited public awareness, and insufficient adoption of advanced treatment technologies. Rapid urbanization and industrial growth exacerbate these issues, necessitating a holistic strategy. Effective solutions require strengthening policy enforcement, fostering partnerships across governmental, non-governmental, and local levels, and equipping communities with the knowledge and tools to participate in water management. Adopting sustainable agricultural and industrial practices is also critical for reducing the long-term pollution burden. This study calls for an integrated, multi-sectoral response that balances policy reform, community engagement, and sustainable practice adoption. Key recommendations include enforcing stricter industrial discharge controls, advancing cost-effective wastewater treatment, and increasing public awareness initiatives on pollution's health impacts. Immediate, coordinated action is essential to safeguard Nepal's water resources, curtail health and environmental damage, and support a sustainable and resilient future for all communities.

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