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Environmental Impact Assessment of Rooppur Nuclear Power Plant

Abstract: The Rooppur Nuclear Power Plant (RNPP), inaugurated in 2013, marks Bangladesh's first step towards nuclear energy, aiming to address the country's electricity demands sustainably. This paper presents an Environmental Impact Assessment (EIA) and audit of RNPP, focusing on the plant's impacts on the local environment, socio-economic conditions, and socio-cultural aspects. The research draws on field observations, household surveys, focus group discussions (FGDs), and key informant interviews, along with secondary data from journals, reports, and online sources. Using the Environmental Impact Value (EIV) tool, the study quantifies the plant's effects on water quality, air quality, soil health, and biodiversity. Additionally, the socio-economic impacts on employment, local infrastructure, and community well-being are evaluated. Safety aspects, including radioactive waste management, effluent treatment, and human safety protocols, are also analyzed to ensure compliance with national and international standards. This study concludes that while the RNPP offers significant benefits in terms of energy security, it also requires continuous monitoring and mitigation efforts to minimize environmental and socio-economic risks.

Introduction:

The Rooppur Nuclear Power Plant (RNPP) represents Bangladesh's first foray into nuclear energy, an effort aimed at meeting the country's growing energy demands while reducing dependency on fossil fuels. Inaugurated in 2013, the RNPP is situated on the banks of the Padma River in the Ishwardi Upazila of Pabna District. With a projected capacity of 2,400 MW, it is expected to significantly contribute to the nation's power grid, enhancing energy security and fostering economic growth (World Nuclear Association, 2019). However, like any large-scale industrial

project, the plant poses potential environmental, socio-economic, and socio-cultural challenges that must be thoroughly assessed and mitigated. An Environmental Impact Assessment (EIA) is critical for understanding and managing the risks associated with nuclear power plants. The EIA for the RNPP considers factors such as the potential for thermal pollution, radioactive waste management, and impacts on local ecosystems and community health (Ahmed & Hossain, 2022). Additionally, the Environmental Impact Value (EIV) tool is employed to quantify these impacts, enabling better decision-making and mitigation strategies. Given the location of the RNPP near a major river and populated areas, environmental monitoring and safety management are crucial components of its operation. Concerns about radiation safety, waste disposal, and effluent management must be addressed to protect both the environment and nearby communities (Bangladesh Atomic Energy Commission, 2021). Furthermore, socio-economic impacts, including job creation, changes in land use, and effects on local infrastructure, must also be considered to ensure that the benefits of the plant outweigh the potential drawbacks.

Rooppur NPP at a Glance

Units:	2 × 1,200 MWe (gross)
Reactor Type:	VVER, Model: V-523
Design:	AES-2006, VVER-1200, Generation III+
Design life:	60 years
Owner:	Bangladesh Atomic Energy Commission
General Contractor:	JSC Atomstroyexport (Subsidiary of Russia's State Atomic Energy Corporation ROSATOM)
Main Water Source:	Padma River

Literature review:

Nuclear energy is regarded as a vital solution to the global demand for clean, low-carbon energy. However, nuclear power plants (NPPs) pose significant environmental and social risks, including radioactive waste, thermal pollution, and radiation exposure. Environmental Impact Assessments (EIAs) and environmental auditing are critical tools in mitigating these risks. The Rooppur Nuclear Power Plant (RNPP), Bangladesh's first nuclear facility, underwent an extensive EIA process to ensure its development meets international environmental safety standards. The EIA process is essential for nuclear projects due to their complexity and high-risk nature. It focuses on radiation safety, waste management, and impacts on natural resources (Lokhov, 2011). The RNPP's EIA included air and water quality assessments, soil testing, biodiversity surveys, and radiation risk modeling. Following International Atomic Energy Agency (IAEA) protocols, Bangladesh ensured the integration of safety measures (Ali & Rahman, 2020).

Radiological contamination is a primary concern, requiring predictive models like RESRAD to simulate radiation dispersion and assess potential exposure risks. These models informed the design of safety protocols for RNPP (Belyakov & Galushina, 2016). Water quality impacts, specifically thermal pollution, were mitigated by using hydrological models to predict the effects of cooling water discharge on the Padma River (Islam & Haque, 2019). Environmental auditing, a key part of nuclear project oversight, ensures ongoing compliance with EIA recommendations. Continuous monitoring of air, water, soil, and radiation levels is crucial for the safe operation of RNPP (Chen et al., 2018). Auditing reports are submitted to national and international regulatory bodies to maintain transparency and compliance (Bogatov & Petrosyants, 2014). Stakeholder engagement is also essential, as public concerns about radiation and displacement can lead to opposition. Involving local communities in consultations helped build trust and social acceptance of the RNPP project (O'Faircheallaigh, 2010; Islam & Hasan, 2020). In conclusion, the RNPP's EIA and environmental auditing have been vital in aligning the project with global safety standards, ensuring the protection of both the environment and public health. Continuous monitoring and stakeholder involvement are crucial for the plant's long-term success.

Materials and Method:

Nuclear fuel: The Mixed Oxide nuclear fuel is made from reprocessed uranium and plutonium. It's a process of nuclear reprocessing. They are capable of sustaining and undergoing nuclear fission. The three most relevant fissile isotopes are plutonium-239, uranium-238, uranium-235, and uranium-233. Uranium is the most widely used as fuel by nuclear plants for nuclear fission. Rooppur nuclear power plants use a specific type of uranium—U-235 as the best fuel.

The capacity of Rooppur Nuclear Power Plant: The Rooppur Nuclear Power Plant will be equipped with two Russian VVER reactors, each with power generation capacity of 1,200 MWe. The referential project for Rooppur NPP is Novovoronezh II NPP in Russia, which is a unique new Generation 3+ power unit with a VVER-1200 reactor. Under the two units of the Nuclear Plant project, 2,400 MW of electricity will be generated. The electricity generated at the NPP will be transmitted through different parts of the country. Hopefully, the two units of Rooppur NPP are expected to go into producing electricity in 2023 and 2024. This power plant is one of the most important projects of the Bangladesh Government. It is being implemented under financial and technical assistance from Russia. Rooppur NPP will play an important role in providing a stable base load and ensuring energy security of the country. Rooppur Nuclear Power Plant will be equipped with the latest generation of two VVER-1200 water-cooled and water-moderated power reactors of the AES-2006 / V-392M design. And each construction stage at this power plant is closely monitored by the national nuclear authority BAEC and the International Atomic Energy Agency (IAEA).

Study Area: Rooppur Nuclear Power Plant, Ishwardi, Bangladesh

Ishwardi is one of the Upazilas in the district of Pabna under Rajshahi division, Bangladesh. Rooppur Nuclear Power plant situated on the bank of Padma River at Rooppur in Ishwardi Upazila in the northwest of the country. The project site is located between 24° 4′ 0″ North latitude and 89° 2′ 50″ East longitude (Bangladesh National Portal, 2017). The study area conducted in 3km diameter circle area at RNPP site. Zhautola, Railway officer' s colony, Paksey Babupara, MS colony, Marin para, Paper mill colony, Fisherman colony, Notun Rooppur, Chor Shahapur, Shahapur, Pakuria and Pilot para are covered the study area.

The site for the RNPP is characterized by a mix of agricultural lands and rural settlements, typical of Bangladesh's floodplain regions. The Padma River plays a significant role in the area, providing water resources for irrigation, domestic uses, and now for the cooling processes of the nuclear reactors. However, the region is also prone to seasonal flooding, and thus, the environmental impact assessment (EIA) of the plant must consider both water resource management and flood risks.

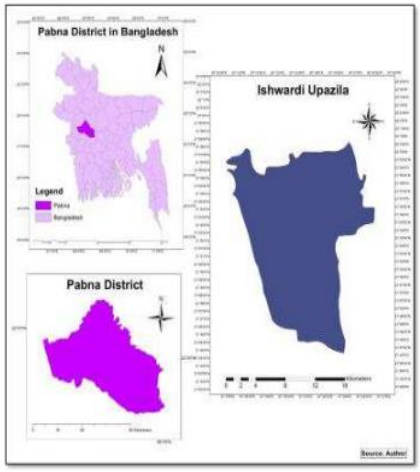

Fig. 1. Ishwardi Upazila in context of Bangladesh

Source: Google Earth Pro, 2020

Fig. 2. 3Km diameter circle area from RNPP Site

Data Collection:

Field observations, household surveys, FGD, and key informant interviews were used to obtain primary data. Office personnel, informed local residents, including community members, merchants, teachers, and political leaders, were questioned to ascertain their perceptions of the project's social and environmental consequences. 3 km circular area at surrounding Rooppur Nuclear Power Plant is selected as the study area for this research. Secondary data were collected from different sources such as web browsing, daily newspapers, official documents, journal articles, photos, reports and so on

Data Sources:

- **Primary Data**: Collected through direct surveys and monitoring efforts conducted by soil and environmental students and field personnel.
- **Secondary Data:** Obtained from government reports, scientific publications, satellite imagery databases (NASA, NOAA), and environmental agencies such as the Bangladesh Department of Environment (DoE) and the Bangladesh Atomic Energy Commission (BAEC)

Impacts of Rooppur Nuclear Power Plant:

Certainly! Here's a more detailed exploration of the various impacts of the Rooppur Nuclear Power Plant across different dimensions:

Environmental Impacts

- ✓ **Land Use:** The establishment of Rooppur nuclear power plant has resulted in the acquisition of a substantial amount of land, resulting in disruption of existing ecosystems and soil erosion and loss of large amounts of agricultural land. Land use changes to agriculture or natural areas have resulted in habitat fragmentation, affecting local wildlife.

- ✓ **Biodiversity:** This project is causing massive loss of biodiversity including death of various birds due to organized pollution. Which is destroying the balance of the environment.

Ecological Impacts

- ✓ **Water Ecosystems:** The plant will draw large volumes of water from nearby sources for cooling, which can lower water levels and affect the hydrology of local ecosystems. This can impact fish populations and other aquatic organisms, leading to shifts in community structures.

- ✓ **Thermal Pollution:** The discharge of heated water back into natural water bodies can raise temperatures, altering the ecological balance and potentially harming sensitive aquatic species that cannot tolerate temperature fluctuations.

Societal Impacts

- ✓ **Economic Development:** The nuclear power plant is generating economic growth through job creation in both construction and operation phases. As a result of this, new urbanizations have been created, "Green City" being one of them.

- ✓ **Community Displacement:** Many people faced displacement or resettlement due to the establishment of this project, resulting in social disruption. As a result, houses and agricultural land have been extensively damaged.

Health Impacts

- ✓ **Radiation Exposure:** Concerns about potential radiation exposure for workers and local residents are paramount. Even though nuclear facilities are designed with safety in mind, any perceived risk can lead to anxiety and stress among communities.

- ✓ **Public Health Infrastructure:** The plant's presence may necessitate improvements in local health infrastructure to address concerns about nuclear safety. This can have positive side effects, enhancing overall community health services.

Wildlife Impacts

- ✓ **Habitat Loss:** The establishment of this project has degraded local wildlife habitats and affected species that depend on certain environments.

- ✓ **Migration Patterns:** This development has forced the migration routes of birds and other animals to change. So, they have a challenge to survive.

Air Quality

- ✓ **Construction Emissions:** Dust from construction machinery and smoke and dust emitted from vehicles transporting construction equipment are negatively affecting local air quality.

- ✓ **Long-term Emissions:** While the operational phase of the plant itself generates minimal air pollution, any accidents or incidents could lead to significant environmental and health repercussions.

Water Quality

- ✓ **Contaminant Risks:** Potential leaks or spills of hazardous materials during construction and operation pose risks to local water bodies, leading to contamination that can affect drinking water sources and aquatic life.

- ✓ **Aquatic Ecosystem Health:** Changes in water quality due to thermal discharges or chemical pollutants can lead to algal blooms, reduced oxygen levels, and a decline in fish populations, disrupting local fisheries and livelihoods.

Cultural Impacts

- ✓ **Heritage Sites:** The area around Rooppur may contain historical or archaeological sites. Construction activities could inadvertently damage these sites, leading to the loss of cultural heritage. Again, the construction of this project has resulted in the creation of various tourist centers in the vicinity. Which is increasing the cultural heritage of the place manifold.

- ✓ **Community Identity:** Changes to the landscape and local economy due to the nuclear plant can alter community identity, affecting local traditions and social cohesion. This can lead to resistance from communities that feel their way of life is threatened.

Result & Discussion:

By using secondary data, The Environmental Impact Value (EIV), which is an actual value of environmental consequences, is used to assess whether an activity positively or negatively impacts the environment. In this paper, EIV was analyzed based on three parameters: environmental parameters and socio-cultural parameters. This study's relative importance value and relative impact were measured based on respondents' perceptions on change of any components or condition. defined either in the caption or in a legend provided as part of the figure.

Table 1. Estimation of Environmental Impact Value (EIV)

Components	Relative importance value	Degree of impact	Relative impact	Individual EIV
Environmental Parameters				
Water quality	15	-2	-30	-65
Aquatic ecosystem	15	-3	-45	
Sound Pollution	2	-1	-2	
Rise of temperature	4	-1	-4	
Forest	8	0	0	
Plantation	3	+1	3	
Vegetation Cover	8	-4	-32	
Greenhouse emission	15	+5	75	
Particulate matter	4	-2	-8	
Regional ecosystem Change	8	-2	-16	
Aquaculture	10	-3	-30	
River Excavation	8	+3	24	

Socio-Cultural Parameters				
Migration	20	-4	-80	-130
Language	8	0	0	
Religion	7	0	0	
Public Health	10	-2	-20	
Culture	10	0	0	
Community build up	10	-4	-40	
Social-well being	12	-3	-36	
Cultural heritage	6	0	0	
Knowledge transfer	12	+3	36	
Attitude of the society to the foreign people	5	+2	10	

After observing and calculating all the components, authors were able to find out the results. This result shows negative impacts on environmental parameters (-65) and socio-cultural parameters (-130). Most of the negative impacts were land acquisition, construction and operation of warm water after energy production related and it is possible to manage effectively.

There is no information that any country in the world as densely populated as Bangladesh where a nuclear plant has been set up. This factor was taken into consideration when the feasibility study was carried out for the Rooppur nuclear power plant project. However, the Indian state of West Bengal has an environment similar to ours. The Indian government has taken up a plan to construct a nuclear power plant there, but the West Bengal government rejected it. An important factor in such projects is to have an evacuation plan in times of crisis. If any accident occurs in a nuclear plant, the people in the surrounding areas must be shifted away immediately. They have to be taken at least 20 km away from the plant immediately to avoid radiation. Like any other part of the country, Rooppur in Pabna district is densely populated. There is no information on how, if the need arises, these people in the areas adjacent to the plant can be removed from the area, how fast they can be removed, where they can be taken and what preparations are required. The local people must also be made aware of this.

The Rooppur Nuclear Power Plant represents a significant advancement in Bangladesh's energy sector, yet it raises crucial environmental concerns that necessitate a thorough Environmental Impact Assessment (EIA) and ongoing environmental auditing. The EIA is a systematic process designed to evaluate the potential environmental effects of the plant, aiming to identify, predict, and mitigate adverse impacts before the project proceeds. A comprehensive EIA involves several key components, starting with scoping, where stakeholders and experts identify critical environmental issues to address. This is followed by baseline studies, which gather data on existing conditions—such as air and water quality, local biodiversity, and socio-economic factors. Impact analysis is central to the EIA, assessing how the plant's construction and operation could affect these parameters. For instance, the potential for thermal pollution, habitat disruption, and effects

on local water resources are significant concerns. The EIA not only outlines these impacts but also recommends mitigation strategies to minimize harm, ensuring that environmental considerations are integrated into project design. Public participation is a vital element of the EIA process, fostering transparency and allowing local communities to voice their concerns. Engaging stakeholders helps build trust and can lead to more effective and accepted mitigation measures. However, challenges such as data gaps and varying levels of community engagement can complicate the EIA process. Once the plant is operational, environmental auditing plays a crucial role in ensuring compliance with environmental regulations. Audits provide ongoing assessments of the plant's environmental performance, evaluating whether mitigation measures are effective and identifying any necessary adjustments. This process involves regular monitoring of emissions, water usage, and ecological impacts, allowing for adaptive management practices that respond to real-time data and changing conditions. Despite its importance, the EIA and auditing processes face challenges, including the need for robust data and the complexities of engaging diverse stakeholders. Additionally, dynamic environmental conditions may require periodic updates to both the EIA and auditing practices. The EIA and auditing of the Rooppur Nuclear Power Plant are essential for balancing the nation's energy needs with environmental sustainability. By rigorously assessing potential impacts and ensuring compliance through audits, stakeholders can foster a responsible approach to energy development that prioritizes ecological health and community well-being. Engaging in ongoing dialogue among project developers, regulatory bodies, and local communities will enhance the effectiveness of these processes, contributing to a sustainable future for Bangladesh.

People awareness of this area:

Survey question	Response category	percentage
People awareness about environmental impact on rooppur nuclear power plant	Very aware	25%
	Some what aware	45%
	unaware	30%

Recommendation:

1. Water Resource Management and Thermal Pollution Control

The RNPP is located near the Padma River, which is crucial for cooling the reactors. To mitigate thermal pollution and ensure sustainable water usage, the following strategies can be implemented:

- **Cooling System Upgrades**: Implement **closed-loop cooling systems** or **cooling towers** to reduce the amount of heated water being discharged into the Padma River. These systems can recycle water and significantly lower the temperature of the discharge.
- **Thermal Discharge Monitoring**: Continuously monitor water temperature at the discharge point and downstream areas to ensure compliance with environmental standards. Use real-time sensors to detect any rise in river temperature that could affect aquatic ecosystems.
- **Discharge Diffusers**: Install discharge diffusers in the river to spread out the heated water over a larger area, reducing the localized impact of higher water temperatures on fish populations and other aquatic life.
- **Water Usage Optimization**: Ensure efficient use of river water for cooling purposes by implementing **water-saving technologies** and reducing unnecessary water withdrawal, especially during dry seasons.

2. Radioactive Waste Management

Proper management of radioactive waste is essential to prevent soil, water, and air contamination. The following measures should be taken:

- **On-Site Storage and Containment**: Implement robust containment systems for short-term storage of low- and intermediate-level radioactive waste. Ensure that all storage facilities are leak-proof and regularly inspected.
- **Long-Term Waste Disposal**: Collaborate with international experts to develop **geological repositories** for high-level radioactive waste. These repositories should be located in geologically stable areas, far from population centers and water sources.
- **Waste Transport Safety**: Strictly regulate the transportation of radioactive waste to ensure safe handling and minimize the risk of accidents. Ensure that transport routes avoid populated areas and environmentally sensitive zones.
- **Radiation Monitoring**: Install **radiation detection systems** around the plant and waste storage facilities to monitor for any potential leaks or accidental releases of radioactive materials. Immediate response protocols should be established in case of any detection.

3. Air Quality Protection

Air emissions from the plant's construction and operation phases can affect local air quality. The following measures can help mitigate these impacts:

- **Emission Control Technologies**: Install state-of-the-art emission control technologies on construction equipment, transport vehicles, and any backup diesel generators. This will

reduce the release of particulate matter (PM10, PM2.5), nitrogen oxides (NOx), and sulfur oxides (SOx).

- **Green Belt Development**: Establish a **green belt** around the power plant to absorb pollutants, act as a buffer zone, and improve air quality. Trees with high carbon-sequestration abilities and tolerance to local climate conditions should be planted.
- **Dust Control During Construction**: Implement dust suppression techniques such as **sprinkling water** on roads and construction sites, using dust screens, and covering transported materials to prevent particulate matter from spreading into nearby communities.

4. Biodiversity and Ecosystem Conservation

The Ruppur region is home to diverse species of flora and fauna. To preserve biodiversity and reduce habitat disruption, the following strategies can be employed:

- **Habitat Conservation Zones**: Identify and protect key ecological habitats around the plant site. For sensitive areas such as wetlands or riverine habitats, establish **buffer zones** where human activities are restricted.
- **Wildlife Corridors**: Develop **wildlife corridors** that allow animals to move freely between habitats without being disrupted by construction or operational activities. This is particularly important for species living near the Padma River.
- **Aquatic Ecosystem Protection**: Regularly monitor aquatic species in the Padma River and mitigate any disruptions caused by changes in water temperature or water quality due to plant operations. Artificial fish habitats can be introduced to support local fish populations.
- **Afforestation and Reforestation**: Engage in **afforestation** and **reforestation projects** in nearby areas to restore natural habitats, improve air quality, and enhance the carbon absorption capacity of the region.

5. Flood Risk Management

Since the area surrounding RNPP is flood-prone, it is essential to mitigate flood risks to protect both the plant and the surrounding environment.

- **Flood-Resistant Design**: Ensure that all plant infrastructure is designed to withstand extreme weather events, including floods. Critical components such as reactors and waste storage facilities should be elevated or protected by flood barriers.
- **Flood Monitoring and Early Warning Systems**: Implement **flood monitoring systems** that provide real-time data on river water levels and predict flood events. Early warning systems should be put in place to alert plant operators and local communities.

- **Drainage Systems**: Develop efficient **storm water drainage systems** to divert floodwaters away from the plant site and surrounding areas, reducing the risk of inundation.

6. Community Health and Safety

To safeguard the health of local communities, the following mitigation strategies should be prioritized:

- **Public Health Monitoring**: Conduct regular **health assessments** of local communities to monitor for any increase in radiation exposure, respiratory illnesses, or other health concerns associated with the plant's operations.
- **Emergency Preparedness Plans**: Establish comprehensive **emergency preparedness and evacuation plans** for the surrounding communities in case of any accidental radiation release or other environmental hazards. Public drills and education programs should be conducted regularly.
- **Public Engagement and Awareness Programs**: Organize awareness programs to educate local communities about the plant's environmental and safety measures. **Transparent communication** regarding potential risks and safety protocols will help build public trust.
- **Noise Pollution Mitigation**: Install noise barriers around high-noise areas, particularly during construction, to reduce the impact on local residents. Limit noisy operations to daytime hours and monitor noise levels regularly.

7. Continuous Monitoring and Auditing

Ongoing monitoring and environmental auditing are essential for tracking the effectiveness of mitigation measures and ensuring compliance with environmental regulations.

- **Environmental Monitoring Stations**: Set up continuous monitoring stations to track air and water quality, radiation levels, soil health, and biodiversity indicators in real-time.
- **Regular Environmental Audits**: Conduct periodic environmental audits to assess the plant's compliance with national and international environmental standards. Reports from these audits should be made publicly available.
- **Adaptive Management**: Based on monitoring results, adopt an **adaptive management approach** to modify and improve mitigation measures over time as new challenges or environmental changes arise.

8. Sustainable Energy Practices

To mitigate the overall environmental footprint of the RNPP, the following sustainable practices can be integrated into its operations:

- **Energy Efficiency**: Improve the energy efficiency of the plant's systems to reduce resource consumption and lower emissions. This could involve upgrading to energy-efficient machinery, implementing energy-saving technologies, and reducing waste in energy production.
- **Renewable Energy Integration**: While the RNPP itself is a non-fossil-fuel-based power plant, it can still support the integration of **renewable energy sources** (e.g., solar, wind) in nearby communities to further reduce reliance on fossil fuels and promote clean energy.

Conclusion

The construction and operation of the Ruppur Nuclear Power Plant (RNPP), Bangladesh's first nuclear power facility, hold significant promise for the country's energy security and economic development. However, such large-scale projects inevitably carry environmental and social impacts that must be thoroughly assessed, managed, and mitigated. The Environmental Impact Assessment (EIA) of RNPP revealed potential risks to local ecosystems, water resources, and community health, particularly concerning radiation exposure and the disposal of radioactive waste. Effective mitigation strategies, such as stringent monitoring, efficient waste management protocols, and public awareness campaigns, are critical to minimizing these risks. The audit of RNPP's environmental performance underscores the importance of ongoing scrutiny throughout the plant's life cycle. Regular environmental audits ensure compliance with national and international safety standards, address unforeseen environmental concerns, and help refine the plant's operations to enhance sustainability. Through robust environmental monitoring and responsive auditing mechanisms, RNPP can balance its contributions to energy security with the imperative of safeguarding the environment and local communities. In conclusion, while the RNPP is a crucial step toward diversifying Bangladesh's energy portfolio, its long-term sustainability depends on effective environmental management practices. Continuous EIA-based auditing, along with stakeholder engagement, will be essential to ensuring that the plant operates safely and minimizes its environmental footprint. This can serve as a model for future infrastructure projects in the country, fostering sustainable development and responsible resource use.

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