The Nigerian Society of Engineers

Minna Branch

2nd NSE MINNA BRANCH CONFERENCE 2025

Theme:

ENGINEERING INFRASTRUCTURE AND SUSTAINABLE DEVELOPMENT IN POST-SUBSIDY NIGERIA

PROCEEDING

14 - 15 May 2025 10:00am

MITI Multipurpose Hall, Minna Institute of Technology and Innovation, Keterengwari Minna, Niger State.

Conference Overview

The **Conference on Engineering Infrastructure and Sustainable Development in Post-Subsidy Nigeria** was convened to address the pressing challenges and emerging opportunities facing Nigeria's infrastructure sector in the wake of the government's decision to remove fuel subsidies. The conference brought together a diverse mix of engineers, government officials, industry experts, researchers, urban planners, environmentalists, and development partners.

Against the backdrop of economic reform and energy market liberalization, the conference sought to explore how engineering can drive sustainable development, reduce inequality, and enhance the resilience of Nigeria's built environment. It served as a timely forum to chart pathways for infrastructure delivery that are both economically viable and environmentally responsible in a subsidy-free policy environment.

Key Objectives:

- To evaluate the impacts of fuel subsidy removal on infrastructure planning, construction, and maintenance.
- To promote sustainable engineering practices that align with global best standards.
- To discuss innovative financing and policy models for infrastructure development.
- To encourage cross-sector collaboration in addressing Nigeria's infrastructural deficits.

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Determination of Failure Mode and Effect Analysis on Water Treatment Plant in Greater Lokoja Water Works

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Abstract: *Water is essential to Nigerian agriculture, household necessities, and industrial purposes. Several issues, including population expansion, maintenance, inadequate water infrastructure, pollution, and climate variability, make it increasingly difficult to obtain safe water for consumption. The problem of water supply in Lokoja and its environment has been a challenge. This problem is caused by failure of the plant components that lead to the downtime of the plant hence, low production. It can be addressed by using Failure Mode and Effect Analysis (FMEA). This research is aimed at determining the failure mode and effect analysis on water treatment plants in greater Lokoja water works. Data were collected using Fuzzy Failure Modes and Effect Analysis (FMEA) technique and analyzed using phyton software. The result shows that FMEA is technique is effective in addressing the water challenges in Lokoja cities. The G2 (pipe) has the highest percentage of 8.9%; B1 (valve), B2(valve) and E1(membranes) have the lowest percentage of 5.0%. C1(filtration system) has the highest percentage of 9.3% and A2, B1(valve), D2(chemical dosing system), E2(membranes) and G2(pipe) have the lowest percentage of 5.3%. A1(pump) and C1(filtration system) have high percentage contribution of 8.0%. B2(valve), E2(membranes) and F1(water storage system) have the lowest percentage contribution of 5.3%. Preventive and corrective action plans were equally developed to address the frequent breakdown of water supply components and machines.*

Key Words: Detectability, Failure Modes, Occurrence, FMEA, Mitigation strategies and Severity.

1. INTRODUCTION

Water is essential to Nigerian agriculture, energy production, household necessities, and industrial operations (Alizadeh and Solimanzadeh, 2015). It is a vital resource that supports many socioeconomic activities and keeps life alive. Water is essential to Nigerian agriculture, energy production, household necessities, and industrial operations (Alizadeh and Solimanzadeh, 2015). Several issues which includes population expansion, inadequate water infrastructure, pollution, and climate variability, makes it increasingly difficult to obtain safe water to consume (Oluwagbemi et al., 2023). Water resources are essential to produce energy, especially for the development of hydroelectric power, which makes a substantial contribution to the renewable energy industry. Water bodies are crucial for the protection of biodiversity because they serve as natural habitats for a variety of ecosystems (WWF, 2022). A comprehensive strategy to manage conflicting demands and safeguard water ecosystems is necessary for constant availability of water (GWP, 2020). Conventional water treatment plants (surface water treatment) are common methods for treating surface water like rivers, lakes, or reservoirs as shown in figure 1. Life without treating portable water is difficult. The processing of large quantities of raw water into portable treated water for human consumption and industrial purposes has been faced with so many challenges ranging from resource unavailability (due to poor maintenance practice) to managerial problems. One of the major resources needed is the water treatment plant (Buana, 2018).

Figure 1: Surface water treatment plant (E., D., 2024)

Poor management of water treatment plants such as the case of the current study hinders the people from deriving the needed benefits associated with large water supply facilities. The absence of efficient maintenance schedules for water plants has made the treatment of raw water very difficult and hence, made the availability of portable water difficult for the people (Gong *et al.*, 2021). The current study will embark on the evaluation of the failure modes and effect analysis towards designing an efficient maintenance schedule for the use of Lokoja Greater water scheme.

This study aims to determine the failure mode and effect analysis of the treatment plant using Greater Lokoja Waterworks, Lokoja, Kogi State as a case study and the objectives are to: identify critical failure modes of components and examine their effects on the water treatment plant; investigate the severity of each failure modes on the water treatment plant and to design a maintenance schedule that mitigates the failure modes

2 REVIEW OF RELATED WORK

The risk assessment and prioritization were considered the following approaches are used for risk assessment and prioritization of components in the water treatment plant according to (Pechstein *et al.* 2022). These uses FMEA to find critical components and processes in a water treatment facility that are prone to failure of water treatment plant. Compliance and safety of the water treatment plant can be achieved by regulatory compliance according to Huang *et al*. (2022), failure to identify possible flaws that could lead to a breach of water quality standards, such as a malfunctioning disinfection system that results in inadequate removal of pathogens, would be against health regulations.

The effectiveness of FMEA on water treatment plants according to Yildirim *et al.* (2023), discovered that FMEA greatly lowers the likelihood of major failures in healthcare settings by helping to systematically address and mitigate risks.

Enhancement of process dependability on failure modes should be prioritized according to their possible impact and likelihood by FMEA, which helps to increase dependability (Al-Fares *et al*., 2022).

Li and Zhang (2022), using FMEA in product design saved costs by foreseeing and averting probable flaws in the early stages of design. According to research by Gupta and Patel (2023), identifying and addressing safety-critical failure modes, lowering liability risks, and improving compliance, FMEA helps firms to achieve regulatory standards. Despite its benefits, studies also point out implementation Difficulties with FMEA, including subjectivity in risk prioritization and a large time and resource requirement (Hansen *et al*., 2022).

Inadequate Integration with Other Risk Assessment Tools: Mohamed and Ahmed, (2023) stated that FMEA is occasionally carried out independently in water treatment facilities without integration with other reliable risk assessment tools, including Hazard and Operability Studies (HAZOP) or Fault Tree Analysis (FTA) which may reduce the findings' comprehensiveness and limit the development of efficient mitigation strategies. FMEA frequently makes use of subjective assessments, especially when determining risk indicators such as detectability and severity depending on the assessors' level of experience; this subjectivity can vary greatly, which could produce biased or inconsistent results (Smith *et al*., (2021).

Water Treatment Plants (WTPs) are using Failure Mode and Effects Analysis (FMEA) more frequently as a proactive method for risk assessment and mitigation by locating potential weak places in processes, it enables WTP operators to handle problems before they get worse. Important discoveries from current research highlighted how well it works to improve operational safety, efficiency, and reliability. Prioritizing failure modes according to severity, occurrence, and detectability (SOD) allows the FMEA to offer an organized method for identifying and evaluating risks. Process Optimization: FMEA encourages process optimization in WTPs by identifying major failure areas. It is possible to identify and replace redundant or defective components, improving efficiency and lowering downtime

Improving Safety Standard Compliance: Strict safety and environmentally friendly regulations must be followed by many WTPs. According to Zhang *et al*. (2023), the implementation of preventive actions and early risk assessment by FMEA can reduce the possibility of regulatory violations and environmental impact, hence supporting compliance.

It has been shown that proactive risk reduction through FMEA reduces costs in WTPs. Over time, it reduces operating expenses by extending the lifespan of equipment and reducing repair costs due to failure prevention. Since FMEA is iterative, it promotes a culture of continuous improvement. New insights are revealed by every cycle of analysis, which eventually leads to further modifications and a reduction in risk according to recent research, FMEA plays a crucial role in streamlining water treatment procedures by increasing dependability, adhering to regulations. According to recent studies, FMEA plays a key role in streamlining water treatment processes by enhancing reliability, meeting regulations, and facilitating economical operations in wastewater treatment plants (WTPs).

2. MATERIAL AND METHODS

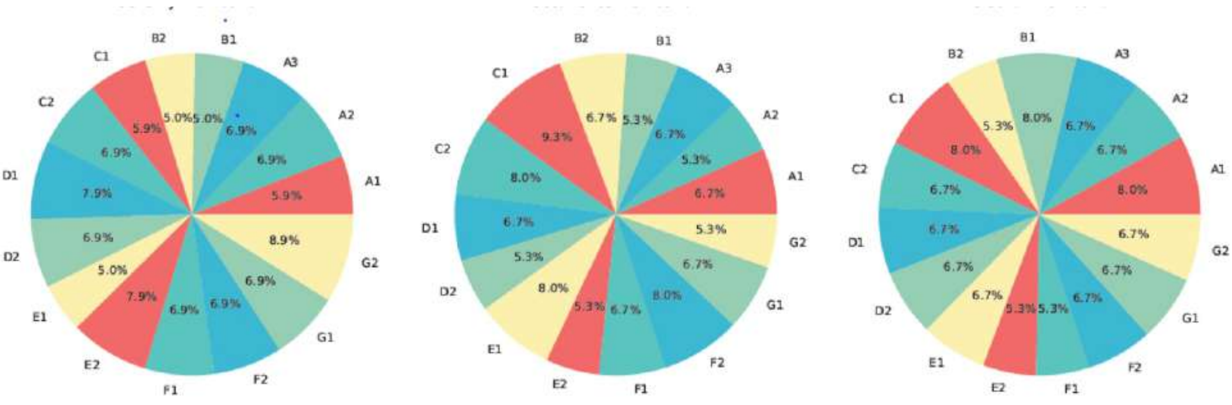
Data for the study was collected from maintenance logs, owner's manuals, and field observations. The FMEA team consisted of engineers, plant operators, and maintenance personnel who worked collaboratively to identify and assess failure modes. The following components were assessed for failure modes: Pumps, Valves. Filtration systems, Chemical dosing systems. Membranes, Water storage systems and Pipes. Each component was analyzed for common failure modes, such as pump seal leakage, valve sticking, filtration clogging, and chemical dosing inaccuracies. The effects of these failures on the overall water treatment process were documented. For each failure mode, the Risk Priority Number (RPN) was calculated by multiplying severity (S), occurrence (O), and detection (D) scores. The RPN was used to prioritize failure modes that required immediate attention.

Pseudocode for the FMEA analysis involves the followings

Review the components,
identify potential Failure Modes and Effects,
Assign severity (S), occurrence (O) and detectability (D) ratings for each effect
Identify potential cause(s) of each failure mode,
Calculate RPN and Take action to mitigate high RPN risk.

4. RESULTS AND DISCUSSION

The challenges of accessible portable water in Lokoja due to frequent break down of the plant components make it necessary to investigate the components towards solving the problems. Hence, seven (7) components of the greater Lokoja water treatment plant was identified, analyzed and evaluated along with their various failure modes, likelihood, severity, detectability and ranking in this work. The mechanical components analyzed in this study are represented by the following symbols: A(pumps), B(valves), C (filtration system), D (chemical dosing system), E(membranes), F (water storage system), and G(pipes)



(a) (b) (c)

Figure 2: Severity, Occurrence and Detection Distribution

Purpose: Show proportional distribution of **S, O, D,**
Method: Three pie charts with percentage labels
Results: Larger slices indicate greater contribution
Outcome: Visualizes relative impact of each component

The severity distribution in figure 2a shows the pie chart distribution of Severity ratings among the analyzed components. The results reveal that, G2 contributes a significant portion of the overall severity profile, implying that their failure would have a disproportionate impact on the system. This distribution underscores the importance of focusing risk mitigation efforts on these components. The occurrence distribution in figure 2b, the occurrence of failures is fairly distributed among the components, although components like C1 display slightly higher frequencies. This indicates that while failure events are relatively widespread, certain components still present a greater probability of failure than others. The detection distribution represented in the pie chart in Figure 2c illustrates the detection ratings across all components. The chart reveals that detection capabilities are unevenly distributed, with components B2, E2, and F1 exhibiting lower detection percentages. This finding suggests a need to enhance diagnostic systems for these vulnerable components.

5. CONCLUSION:

The application of Failure Mode and Effect Analysis (FMEA) in the Greater Lokoja Water Works has demonstrated its potential in identifying critical failure modes, prioritizing risks, and developing effective mitigation strategies. By implementing FMEA, water treatment plants can significantly improve their operational efficiency, reduce downtime, and ensure consistent water quality. The results show that the G2 (pipe) has the highest percentage of 8.9%; B1 (valve), B2(valve) and E1(membranes) have the lowest percentage of 5.0%. C1(filtration system) has the highest percentage of 9.3% and A2, B1(valve), D2(chemical dosing system), E2(membranes) and G2(pipe) have the lowest percentage of 5.3%. A1(pump) and C1(filtration system) have high percentage contribution of 8.0%. B2(valve), E2(membranes) and F1(water storage system) have the lowest percentage contribution of 5.3%. Future research should explore the integration of FMEA with real-time monitoring systems and advanced risk assessment tools to address the dynamic nature of risks in water treatment. Although FMEA has proven effective in identifying and mitigating risks, it has limitations, particularly in addressing dynamic risks like microbiological contamination and chemical interactions. These challenges require the integration of more advanced risk assessment techniques, such as fuzzy logic and real-time monitoring, to enhance the effectiveness of FMEA

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MECHANISTIC-EMPIRICAL DESIGN OF FLEXIBLE PAVEMENT: THE CASE OF NEW NIGER DEVELOPMENT PROJECTS

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Abstract

Flexible pavement on Nigerian roads has recorded early failure, which has disturbed the road users and the Government. New Niger development projects has embarked on roads construction across Niger state by various foreign and indigenous companies. This paper examines the level of compliance with national and International design and construction standards, and uses the Mechanistic-Empirical Design method to predict the cumulative damages and distresses caused by heavy truck traffic. The result shows all the performance criteria were met for a design life span of 20 years except the top-bottom fatigue cracking which was targeted at 378.8m/km and predicted at 941.47m/km at 90% reliability, total permanent deformation predicted 15mm as against threshold level of 19mm, bottom-up fatigue cracking of 20.25% as against 25% threshold level. The study concludes by recommending the inclusion of environmental and climatic factors, such as temperature and groundwater table, in pavement design

Keywords: *Mechanistic-empirical design, flexible pavement, performance criteria, distresses*

INTRODUCTION

The need for a durable and long-lasting road pavement is paramount at any level of government to cater to its infrastructural deficit and to aid transportation problems within the locality. In recent dispensation, where the economy of the country is deteriorating, transportation of goods and services is becoming difficult for the common man, coupled with frequent road pavement failures.

Niger state has most of federal roads spanning across the state with inflow of heavy traffic from southwestern part of the country to northwestern part of it. Niger state serve as a corridor that linked west to north for transportation of manufactured goods from west to north and agricultural