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RESEARCH ARTICLE

INFLUENCES OF CLIMATIC CONDITIONS AND EROSION ON THE STABILITY OF DRINKING WATER SUPPLY PIPELINES IN CENTRAL AFRICA: THE CASE OF KINSHASA

Alassane TOURE [1,*], Dr. Sory DIALLO[2], Dr. Kadaouye DAMBA[1], Adjaratou TRAORE[1] and Dr. Mahamadou Alassane[1]

[1]National Engineering School (ENI/ABT) of Bamako; [2]Technical and Vocational Teacher Training College (ENETP) of Bamako

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**Corresponding author:*
Alassane TOURE

ABSTRACT

This article analyzes the impact of current climatic conditions and erosion processes on the stability and performance of Drinking Water Supply (DWS) pipelines in Kinshasa. In a context well known across coastal countries and particularly in the capital of the Democratic Republic of Congo, we propose a vulnerability assessment protocol, technical and nature-based adaptation measures, and a monitoring model tailored to local constraints. The findings highlight the need to integrate coastal management strategies and targeted engineering protections to significantly reduce the risk of pipeline rupture and repeated exposure of the DWS networks.

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INTRODUCTION

Water is an essential element for the growth and development of all living beings, especially humans (1). Despite Sustainable Development Goal (SDG) 06, more than 663 million people still lack access to improved water sources (2), reflecting inequalities in water consumption per capita across geographic regions (3). As one of the regions most heavily affected by environmental issues (4), the development of drinking water supply networks in tropical Africa—including the Democratic Republic of Congo—remains a critical component of urban services. These challenges increase vulnerability in developing countries where adaptive capacity is limited (5). Exacerbated by climate change, which alters the frequency of extreme events, the region is affected by scouring, flooding, and destabilization of pipeline bedding materials. The severe erosion observed in and around Kinshasa often leads to pipeline exposure, buckling, cyclic fatigue, and rupture. Furthermore, during construction works, landslides can cause environmental and safety risks (including threats to human lives and damage to infrastructure) and significantly impact project timelines. It is therefore essential to examine these phenomena, which Kinshasa shares with many tropical cities.

METHODOLOGY

Study Area Description: This study focuses on the intervention zone of the Kinshasa Multisectoral Development and Urban Resilience Project (PDMRUK-KIN ELENDA) in western Kinshasa. Over the 30-month project period, the scope of works included:

- Supply and installation of 15,175 m of DN 1400/1200/800/300 pipelines (including 7,500 m DN1400, 2,930 m DN1200, 1,260 m DN800, and 2,940 m DN300 in ductile iron), and construction of associated structures. This also included replacing 545 m of DN900 steel pipelines;
- Connections to existing DN500, DN650, DN700, and DN900 steel pipelines.
- Replacement of the existing DN350 steel discharge pipeline from Makala to Selembao with a 1,600 m DN400 ductile iron pipeline.
- Installation of a new secondary distribution reinforcement pipeline along Mafuta Avenue (2,200 m, DN300 ductile iron).
- Supply and installation of 28,200 m of HDPE PN10 pipelines (DE ≤ 315 mm), distributed by diameter.
- Connection of distribution branches to the existing network, five river crossings, an aerial crossing of 228 m at the Makelele Bridge, and erosion protection for the projected pipeline.
- Civil works, including backfilling, road restoration, rehabilitation of drainage structures, and anti-erosion stabilization.

The documents (plans, technical reports) were therefore drawn up in light of this work in order to comply with the fundamental requirements adopted during the laying of pipes.

Terrain Surveys and Data Collection: Field visits were conducted throughout construction to closely monitor erosion phenomena.

Field Observations: Frequent collapses and fissures were observed along multiple sections due to erosion. At some locations, ground movements occurred during trench excavation, forcing route

modifications and creating recurring alignment issues. Quantity discrepancies frequently caused disputes between site inspectors and contractors.

Figure 1. View of the PDMRUK-KIN ELENDA network)

Figure 2. Landslides during the installation of DN 1400 FD pipes

Furthermore, it is after installation that the cracks spread, causing landslides that sometimes attempt to spread under certain structures or weaken the condition of roads.

Figure 3. Effects or impacts on the ground after installation of the DN800

Proposed Operations for Work Continuity: Soil fragility during DWS works in Kinshasa presents a major challenge. To mitigate these risks and ensure project progress as well as protection of underground infrastructure—key assets in urban environments (6). Sheet piles and replacement of excavated soil with imported fill were recommended. This enhances ground stability and provides better protection of trench backfilling against erosion and water flows.

Figure 4. Sheet pile protection operations during construction work

RESULTS AND DISCUSSION

Results

Pipeline Damage Mechanisms: Despite advances in fundamental research in Central Africa, it remains important to assess the current state of knowledge and policy recommendations (5). In Kinshasa, five major phenomena affecting DWS pipelines were identified:

- Local scour causing removal of supporting material and loss of bedding (bending and stress concentrations) ;
- Exposure due to retreat of riverbanks or bed widening, resulting in initially buried pipes becoming exposed ;
- Flotation and displacement where saturated soils reduce friction, causing uplift or sliding of poorly anchored pipes ;
- Accelerated corrosion from saline intrusion and organic soils, reducing pipeline lifespan and Obstruction and blockage from sediment remobilization, affecting chambers, valves, and air inlets.

Adaptation Measures and Recommended Protections: Hard engineering measures include rock armoring, reinforced concrete slabs, gabions, increased burial depth, protective bedding layers, and the use of resistant materials (HDPE, coated ductile iron, cathodically protected steel).

Engineering measures (hard)

- Riprap, concrete slabs, and gabions to limit scouring at river crossings and along the coast.
- Increase in minimum burial depth where feasible + protective bed (compacted sand + geotextile).

Green and integrated measures

Restoration/management of mangroves and mudflats to dissipate wave energy and reduce erosion. Permeable dam techniques and habitat restoration have shown positive effects in other tropical basins.

Governance and planning

- Integration of drinking water supply networks into land use plans and coastal adaptation plans (ICAM).
- Funding for preventive measures (protection and monitoring) rather than ad hoc repairs.

Proposed case study: Given the frequent challenges encountered in similar large-scale projects, a pilot program could be established in Libreville, including coastal inventory, bathymetric surveys, geotechnical investigations, monitoring instrumentation (strain sensors and drone surveys), and mixed protection measures (rock armor + mangrove planting). Expected outcomes include reduced exposure, fewer pipeline failures, and improved system availability.

DISCUSSION

Coastal and fluvial erosion risks are well documented (8), yet their application to DWS networks in Central Africa is limited by lack of local data such as burial depth, updated bathymetry, and sediment behavior. These issues often negatively affect project budgets and timelines. As observed in Bamako, water supply infrastructure development under such constraints becomes central to territorial planning (9). Unfortunately, many residents still lack sufficient water and travel long distances or pay high costs to obtain it (10). Sheet piling remains a cost-effective method for erosion control, while integrated engineering–ecological approaches appear most promising for long-term risk reduction.

CONCLUSION

This practical study aimed to clarify the influence of climatic conditions and erosion on the stability of DWS pipelines in Central Africa, particularly in Kinshasa. Field activities revealed that these phenomena significantly slow project execution and cause serious damage (collapses, landslides, loss of life). Beyond sheet piling for slope stabilization, strong involvement from the Congolese State to combine engineering protections with ecological restoration will be essential for long-term, cost-effective resilience.

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