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# **A Systematic Review of Digital Twin Methodologies for Simulating Industrial Effluent Pollution in African River Basins: A Focus on the Nairobi Basin,**

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# | Abstract

Industrial effluent discharge threatens water quality in African river basins. Digital Twin technology presents a method for simulating pollution dynamics to inform management. Methodologies for applying this technology to industrial pollution in African contexts, however, lack comprehensive synthesis. This systematic review identifies, evaluates, and synthesises documented methodologies for developing Digital Twins to simulate industrial effluent pollution, with a specific focus on applications relevant to the Nairobi River Basin. It assesses the suitability of these approaches for data-scarce environments and outlines a conceptual framework for future implementation. A systematic search was conducted across multiple academic databases. Pre-defined inclusion and exclusion criteria were applied to select peer-reviewed and significant grey literature. Studies were screened, with relevant data on modelling approaches, data integration techniques, and validation methods extracted and thematically analysed. The review identified a predominant reliance on hydrodynamic and water quality models as the core computational engine for environmental Digital Twins. A central theme was the critical challenge of data scarcity, with many studies highlighting the use of surrogate data or simplified model structures as a necessary adaptation. Methodologies specifically tailored to the Nairobi Basin's context were found to be extremely limited. While Digital Twin methodologies hold potential for

simulating industrial pollution in African river basins, existing approaches are largely adapted from temperate regions and may not fully address local data and infrastructural constraints. A significant research gap exists in developing context-sensitive Digital Twin frameworks for basins like the Nairobi. Future research should prioritise developing modular, low-cost Digital Twin architectures that can integrate sparse monitoring data with real-time sensor inputs. Collaborative efforts between academia, industry, and regulatory bodies in Africa are essential to build robust, locally calibrated models for effective pollution management. Digital Twin, systematic review, industrial effluent, water pollution, river basin, hydrodynamic modelling, data scarcity, Nairobi River Basin, Africa. This review consolidates the current state of Digital Twin methodologies for industrial pollution simulation in African river basins, explicitly highlighting the gap in context-specific frameworks and providing direction for future research tailored to local constraints.

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