FACULTY OF ENGINEERING

DEPARTMENT OF WATER RESOURCES ENGINEERING

FINAL YEAR PROJECT

A POLLUTANT TRACKING MODEL FOR THE MITIGATION OF MERCURY-INDUCED CONTAMINATION ON SURFACE AND GROUNDWATER RESOURCES

Case study: River Okame catchment section in Uganda

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ABSTRACT

Artisanal and small-scale gold mining is one of the many economic activities in the world commonly practiced in Asia followed by Africa and then Latin America. In Africa, Uganda is one of the few countries that carryout artisanal mining with this activity carriedout in the central, western, eastern and north-eastern regions of the country. This activity involves use of rudimentary tools to extract the ore and use of mercury to separate the gold from the ore. In eastern Uganda, this activity is more dominant in Tiira, Busia. The continuous use of mercury in the gold-ore separation has led to its continuous accumulation in the water bodies over a long period of time leading to many health complications such as neurobehavioral effects, motor coordination disorders, and cardiovascular diseases. Wanyana et al. (2020) conducted a cross-sectional study from June to July 2018 among 183 miners from Ibanda, Mubende, Amudat and Busia in Uganda. Results from laboratory checkup from miners' urine and blood showed blood and urine to have concentrations of 60 µg/l and 70.6 µg/l of mercury respectively which are above the WHO standards. Alternatives to use mercury for gold-ore separation such as use of Borax has been introduced but has not been adopted because it takes a long time to recover the gold nuggets from the ore which is time wasting. This study focuses on using existing physical models to ascertain the extent the movement of the contaminant in surface and groundwater resources and propose possible mitigation measures to curb the contamination on-site and off-site. This study involved characterization of the mercury concentration, developing pollutant tracking models for mercury transportation and determining optimal mitigation strategies to curb the contamination. A sampling size of 106 peopleconsisting of focused group discussions, miners, household survey and key important persons was analyzed using questionnaire and interviews. Laboratory water quality assessment was done to determine mercury concentration in the existing 13 water points. Surface and ground water quality was modelled in a coupled system of WEAP and MODFlow packages. Optimal mitigation measures were obtained by performing optimal runs in design of experiments analysis. The questionnaires were used to get the community, miners and leaders' perception about mercury usage and its related effects. The mercury sample used at site was analyzed and found to contain other heavy metals such as Lead (0.22mg/l), Nickel (0.093mg/l). Water quality assessment of the river water sampling points yielded high concentrations of mercury and lead of 55.1mg/l and 49.7mg/l respectively. WEAP model calibration yielded an R^2 value of 0.96, NSE value of 0.73 and MODFlow model calibration yielded an R^2 value of 0.76. An optimal value of 0.4567 from the Minitab model that was used to get an optimal measure. Further studies are recommended to be carried out on the River Okame cleansing capacity, sediment transport modelling and model coupling to get a better image of the whole problem in surface and ground water resources.

DECLARATION

DECLARATION

I ANANO GLORIA, WAFULA JULUIS KOGAN and WAMBI MICHEAL declare that this report is a result of our own research and has never been submitted to any institution ofhigher learning for any academic award.

We stand to account for all this information contained in this report and to regret any queries that may arise out of it if there is any.

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Date 16th/01/2023

WAFULA JULIUS KOGAN

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APPROVAL

APPROVAL

This final year research project proposal has been submitted to the Department of Water Resources Engineering under my supervision.

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List of Abbreviations/Acronyms

ASGM - Artisanal and Small-scale Gold Mining

UBOS - Uganda Bureau of Statistics

MWE - Ministry of Water and Environment

DWRM – Directorate of Water Resources Management

GUI - Graphical User Interface

WEAP - Water Evaluation and Planning

NGO - Non-Government Organization

UN - United Nations

USGS – United States Geographical Society

MODFLOW – Modular Flow

1.0 INTRODUCTION

This chapter includes; back ground to the study, statement of the problem, objectives of the study, scope of the study which includes the conceptual scope, geographical scope and time scope and finally the significance of the study.

1.1 Background

Gold mining is the major source of mercury to the lower basin of the river with an estimate of 150-300 kg of mercury released into the river since 1985 (Adler et al., 2018). Globally, most Artisanal and Small-scale Gold Mining (ASGM) located in Asia, with a total average of at least 10.6 million operators followed by Africa (at least 9.9 million) and Latin America (at least 1.4 million) (Intergovernmental Forum on Mining, Minerals, 2018). In Brazil, this activity currently plays an important role in the economy of the country attracting a large number of miners (Balzino et al., 2015).

The Uganda government has begun to focus more attention on the artisanal mining sector because it yields significant profits with profits gained estimating to US$28 million in just a decade. An estimate of up to 200,000 people are directly involved in artisanal mining and about 45 per cent are estimated to be women, although this varies in different regions of the country (Mpagi et al., 2017). In the eastern region, Gold was first discovered in the Busia gold district in 1932 in the Osipiri area. Small-scale mining operations began soon after this discovery in Tiira, Makina, Amonikakine and Osipiri villages and are still going on with mercury used in the extraction process (National & Management, 2019).

The continuous use of mercury has led to its continuous accumulation in the water bodies leading to many health complications such as neurobehavioral effects, motor coordination disorders, and cardiovascular diseases. These are characterized with symptoms like fatigue, dizziness, weakness, tremors and shaking of hand (Wanyana et al., 2020). Since it chronically affects population, its effects can arise over many years and cause severe damage to an entire generation. Studies also show that when pregnant women take in contaminated water and fish it causes many neurodevelopment problems to occur including mental retardation, learning delays, visual and auditory alterations, and other harmful effects due to the fact that the fetal brain is more sensitive to the action of methylmercury (de Bakker et al., 2021).

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