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Research Paper Engineering

Lagrangian Model Framework: A Cutting Edge towards Predicting Pollutants Transport in River Benue of Greater City Yola, Nigeria.

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ABSTRACT

The purpose of this paper is to predict the fate and transport behaviour of pollutants discharged into the Benue River through point and non point sources using Lagrangian equations of fluid motion in MATLAB default environment. To achieve this, water samples were collected from the source of this river at Adamaoua Mountains of Cameroon and Yola, the study area in well preconditioned plastic bottles and analysed for the presence of heavy metals in the river. Findings of this study showed that only Zn, Cu, and Mn concentration levels were below the permissible limits of water quality standards while Fe, Cd, Cr, Ni, and Co values were by far above the threshold limits. The model predicted output indicated a one-dimensional non uniform linear graph of pollutants' movement due to advective forces and water current effects with average water velocity of 0.66m/s covering a travel distance of 1500 meters within 15 minutes.

Key words : : Fluid motion, Transport, Pollution, Model, and River Benue

INTRODUCTION

Pollution in Benue River at the Greater city of Jimeta-Yola can be attributed to many sources such as contaminants from agricultural fields, domestic sewage from the city, chemical wastes from industrial and commercial centers, waste dumpsites, atmospheric deposition, hospital wastes, abattoirs, and so on. This paper will introduce Lagrangian framework to model the travel time and distances of these pollutants in River Benue, located at about one and half kilometers down the slope of Gwari market vegetable waste dumpsites considered as one of the major sources of pollution whose heavy metals and leachates derived from them migrate through rainfall storm water runoff, seepage via soils and open drainages to contaminate the river. The insights gained from this study can be used to understand the unique realities of movement and degradation status of pollutants in surface water flows. Water pollution is the contamination of water bodies (e.g. lakes, rivers, streams, oceans, aquifers and groundwater). It occurs when pollutants are directly or indirectly discharged into water without adequate treatment to remove harmful compounds which affects plants and organisms living in these water bodies. The effect is damaging not only to individual species, but also to the natural biological communities [1]. West Larry [2] asserted that water pollution is a major global problem which requires on-going evaluation and revision of water resources policy at all levels. It has been suggested that it is the leading worldwide cause of deaths and diseases, and accounts for the death of more than 14,000 people daily. Estimates of 580 people in India die of diarrheal sickness every day [3]. Some 90% of China's cities suffer from some degree of water pollution, and nearly 500 million people lack access to safe drinking water. This problem is also peculiar in Nigeria and other developing countries; developed countries continue to struggle with pollution problems as well [4]. Most water pollutants are eventually carried by rivers into the oceans, some of which the influence can be traced hundred miles from the mouth by studies using hydrology transport models. Advanced computer models such as SWMM or the MODFLOW models have been used in many locations worldwide to examine the fate of pollutants in aquatic systems [5]. Many chemicals undergo reactive decay or chemical change especially over long periods of time in rivers. A noteworthy class of such chemicals is the chlorinated hydrocarbons such as trichloroethylene (used in industrial metal degreasing and electronic manufacturing); and tetrachloroethylene used in dry cleaning industry.

Heavy metals contamination in rivers is one of the major quality issues in many fast growing cities, because maintenance of water quality and sanitation infrastructure did not increase along with population and urbanization growth especially for the developing countries [6]. The main natural sources of metals in water are chemical weathering of minerals and soil leaching. The anthropogenic sources are associated with industrial and domestic effluents, urban storm, water runoff, and landfill leachate, mining of coal and ore, and atmospheric sources [7]. Some metals like Cu, Fe, Mn, Ni and Zn are essential as micronutrients for the life processes in animals and plants while many other metals such as Hg, Cd, Cr, Pb and Co have no biological role in the healthy organisms and can cause damage even at very low levels [8]. They are generally non- degradable and accumulate in the human body system, causing damage to nervous system and internal organs. Other adverse effects caused by chemical pollution are eye, nose and throat irritation, headache, allergic skin reaction, dizziness, nausea and difficult breathing. In worst cases long term exposure to chemical pollution can even lead to cancer. As such, in order to reduce the level of global chemical pollution, the world needs to reduce the generation of waste and ensure environmentally safe waste-disposal, ensure better monitoring and adequate laws as well as ensure improved level of care when using different chemicals for agriculture and industries [9]. During the decomposition process of organic compounds released into watercourse, the dissolved oxygen is reduced and it causes the oxygen depletion (anoxia), which have severe consequences for the stream biota. Surface water flow takes into account diffusion, convection, advection, dispersion, and chemical reactions where the pollutants at the upper water parcels mix with the lower water parcels to react with other materials or sediments on the river bed (Chris, 2004). Therefore, there is need to undertake this surface water transport modeling using acquired hydrology data integrated into Lagrangian equations and coded in MATLAB default environment in order to understand the fate and accumulation of pollutants in the Benue River through the following research objectives: (1) to analyze and characterize the presence of heavy metals and other conventional pollutants in the river, (2) develop Lagrangian model of fluid flow to simulate movement of pollutants, and (3) apply the model in MATLAB script file for the prediction of the transport pattern.

METHODS AND MATERIALS

Description of Study Site:

River Benue (French: la Bénoué) previously known as the Chadda River or Tchadda (Fig. 1) is the major tributary of the Niger River [10]. It traverses and drains Jimeta-Yola city and her environs. It is one of the 23 major rivers in Nigeria and passes through the north eastern part of the country. It rises in the Adamaoua Plateau of northern Republic of Cameroon at about 440 feet from where it flows westward; through the town of Garoua and Lagdo Reservoir with a 40m high Dam built across it. After exiting Cameroun, the Benue proceeds Westward, South of the Mandara Mountains, passing through Jimeta-Yola, Numan, Ibi and Makurdi, meeting the Niger River at Lokoja in Kogi State where they together flow through the lower Niger Delta basin and drains directly into the North Atlantic Ocean. Some of the Benue headwater tributaries are born in the South-eastern Chad. The Mayo Kébbi, one of the primary headwater tributaries to the Benue, connects it with the Logone River, an outlet of Lake Fianga (part of the Lake Chad system) forming part of the international boundary between Cameroon and Chad. Other major Benue tributaries in Nigeria are: River Gongola in Adamawa State, River Taraba in Taraba State