Ecological Modelling 353 (2017) 167–173

Contents lists available at ScienceDirect

Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel

Modeling approach to evaluation of environmental impacts on river water quality: A case study with Galing River, Kuantan, Pahang, Malaysia

Ingyu Lee [a], Hyundong Hwang [b], Jungwoo Lee [c], Nayoung Yu [b], Jinhuck Yun [b], Hyunook Kim [a,*]

[a] Department of Energy and Environmental System Engineering, University of Seoul, Seoul, Republic of Korea
[b] Human Planet Ltd., Daejeon, Republic of Korea
[c] Environmental Engineering Research Division, Korea Institute of Civil Engineering and Building Technology, Gyunggi-do, Republic of Korea

ARTICLE INFO

Article history:
Received 31 July 2016
Received in revised form 18 January 2017
Accepted 19 January 2017
Available online 31 January 2017

Keywords:
EFDC
Galing river
Scenario analysis
Water quality modeling
WWTP

ABSTRACT

One of the major issues in Kuantan, Pahang, Malaysia is the water quality of Galing River which is flowing through the area. Currently, overall water quality of the river is very poor, i.e., Class IV (based on the Malaysian water quality standards), mainly due to wastewater discharged from residential area and industries without being properly treated. Due to severe pollution, aquatic ecosystem has not been properly developed. Thus, it is being considered to construct a new wastewater treatment plant (WWTP) to prevent discharge of pollutants and to improve the river water quality. Therefore, this study was conducted to identify the pollution sources along the river and assess their impacts on the water quality. In addition, a numerical model was formulated with the Environmental Fluid Dynamic Code (EFDC) to find a best plan to improve the water quality. Through the model simulation, it was found that wastewater from all the U-drains and culverts along the river should be collected by sewer, transported to a WWTP for treatment, and then pumped to the upstream of the river for discharge. It was also found that if the WWTP would reduce pollution load by 80%, the current water quality of the river would improve by 80% to achieve Class II.

1. Introduction

Urban development without a proper plan often results in environmental issues, for example, deterioration of water quality of rivers, lakes, and reservoirs. In other words, the urban development causes human population and activities to increase and surrounding environment to be polluted. Therefore, the modern cities in western countries have been established through a comprehensive development plan including sewage collection and treatment. However, most cities in the south-eastern Asian countries have been developed without such a plan; wastewater generated from the cities often pollutes a receiving water body since it is discharged without a proper treatment (OECD, 2012). Due to uncontrolled flowing-in of pollutants, i.e., organics, nitrogen, phosphorus, receiving water bodies often experience algal blooming, fish death/floating, and deterioration of biodiversity, eventually negatively-affecting human life (Wang et al., 2014). Thus, many city governments in the countries, e.g., Malaysia, China, Thailand, etc. are building new wastewater treatment plants (WWTPs) to prevent water pollution (Rashidi et al., 2015). When construction of a WWTP is planned, a number of factors should be considered; they include the design capacity, characteristics of the influent, location of the WWTP, and the ecological and beneficial impacts of sewage collection and treatment on the water environment (Ji et al., 2013). Construction of a WWTP including a sewer system involves a huge capital investment and operation and management costs, which are also important factors considered in an urban development plan (Massoud et al., 2009). In order to make a reliable plan for environmentally sound urban development, various scenarios for the plan, each of which considers both economic and environmental consequences, should be made and evaluated. Then, the best one should be chosen (Hernández-Sancho et al., 2015).

Over the past decades, computer models have been applied to assess environmental impacts of a development plan (Wang et al., 2013). Using computer models is more advantageous than doing traditional empirical and experimental models in assessing

* Corresponding author.
E-mail address: h_kim@uos.ac.kr (H. Kim).

http://dx.doi.org/10.1016/j.ecolmodel.2017.01.021
0304-3800/

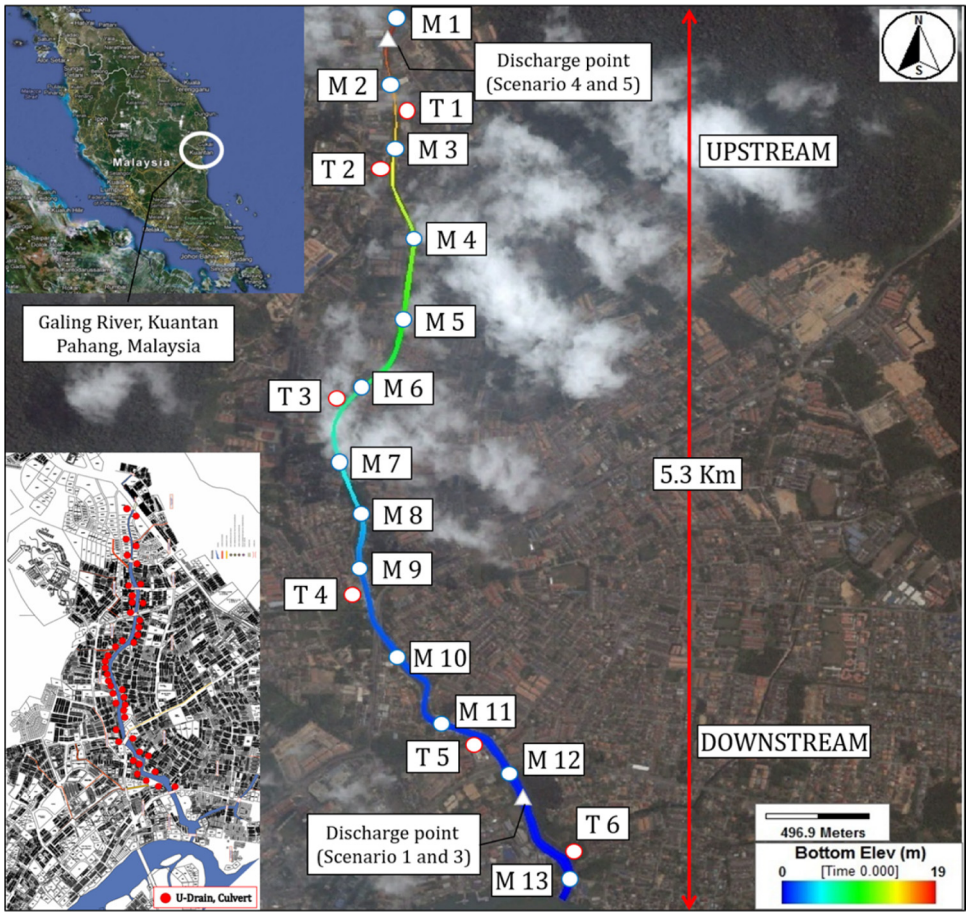

Fig. 1. Sampling locations along Galing River.

environmental impacts of a development and management plan (Beck, 2013; Chen et al., 2014; Liangliang and Daoliang, 2015).

Numerical models have been widely used to evaluate water quality issues in both fresh water and sea water (Park et al., 2005; Seo and Kim, 2011; Shi et al., 2011). As the fresh water environment is concerned, Water quality Analysis Simulation Program (WASP) developed by the United States Environmental Protection Agency (US EPA) in 1983 (Ambrose et al., 1988) has been widely used; for example, WASP was applied for the estimation of regional risk assessment for point source pollution in Taipu River, China (Yao et al., 2015). It also used to simulate water quality of Daliao River and calculate the waste loads for the water environmental capacity of the water body (Lei et al., 2015). Recently, it has been applied to simulate water quality and hydrodynamics of a water body, being linked with the Environmental Fluid Dynamics Code (EFDC) (Luo and Li, 2009; Jeong et al., 2010; Wu and Xu, 2011; Wang et al., 2015); EFDC was also developed by the US EPA (Shoemaker, 1997) and has been applied for simulating three-dimensional flow circulation, mass transport, and biogeochemical processes in rivers, lakes, wetland, and reservoirs (Su et al., 2014; Wang et al., 2014; Yang et al., 2016). In fact, EFDC has been extensively tested and is now considered as a standard model for river and estuary studies (Ji, 2008). For example, Seo et al. (2012) applied EFDC for prediction of *Chlorophyll-a* change of a river before and after construction of weirs. In order to improve water quality of the surface water in terms of dissolved oxygen (DO), *Chlorophyll-a*, COD (chemical oxygen demand), TN (total nitrogen), and TP (total phosphorus), scenario analyses using an EFDC model were also performed (Kang and Jang, 2015). EFDC has been used for calculating allowable pollution loads for streams in an environmental capacity management system (Liang et al., 2015). Seo and Song (2015) applied it for modeling three-dimensional hydrodynamics and water quality of Youngsan River, Korea. Recently, EFDC has been applied in Total Maximum Daily Load (TMDL) programs in which water quality of a watershed is estimated, a few scenarios are set-up and analyzed, and pollution loads are allocated (Kang and Jang, 2015; Wang et al., 2015).

The Malaysian government has initiated a nationwide stream restoration plan to make national waters clean. Kuantan which is the capital city of Pahang, the largest state in Malaysia has also initiated a restoration project for Galing River, the most important branch of Kuantan River flowing through the city. Since there is no WWTP along the river, all the wastewater from nearby residences and industries flows into Galing River. At present, the river is so polluted that almost no aquatic life can be found (Kozaki et al., 2016). Therefore, the city plans to build a WWTP at the downstream of Galing River. In addition, the city, if necessary, intends to pump the treated wastewater to the upstream of the river. Lastly, treatment of all the water from small tributaries (a total of 6 tributaries along Galing River) is also considered; in this case, a treatment facility can be installed at the junction of each tributary and the river. Therefore, this study was conducted to assess the effects of installing a new WWTP for treating wastewater from residential area and polluted tributary water on overall water quality of Galing River. A numerical model was formulated with EFDC and a scenario analysis was performed. A total of five scenarios were set up depending on the discharge point of the WWTP and installation of facilities treating polluted water from six tributaries.