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Assessment of Bagmati river pollution in Kathmandu Valley: Scenario-based modeling and analysis for sustainable urban development

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ABSTRACT

Water pollution remains a challenging issue for the sustainable development of Kathmandu Valley despite several infrastructural, awareness-raising and policy measures. The paper assesses the sustainability of the surface water resources of Kathmandu valley by analyzing the water quality parameters such as Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD). The case study of Bagmati River pollution is analyzed for current and future wastewater production and treatment scenario based on the two important indicators of aquatic health. The DO and BOD were simulated to assess river pollution along a 25 km stretch between Sundarijal and Chovar. Water Evaluation And Planning (WEAP) model was used to simulate the current (year 2014) and future (year 2020 and 2030) river water quality conditions. The results showed that the water quality of the Bagmati River is relatively better during monsoon season due to higher river flow in comparison to the dry season. A comparison of simulated DO and BOD values for 2020 and 2030 with 2014 values indicated that the water quality of the Bagmati River within Kathmandu Valley will not significantly improve as a result of the planned wastewater treatment plants requiring additional countermeasures. The study pointed out the inefficiencies of the current practice of discharging untreated sewage into the surface water and causing largely in the river water and unsuitability of river water of water from the Gaurighat to the Chovar area. It is recommended to integrate river water pollution management and maintain ecologically to achieve the healthy urban development.

1. Introduction

In recent years, the volume of wastewater produced in urban areas has increased substantially because of rapid growth in the human population, industrial production, and commercial activities, as well as changes in water consumption behavior. In most urban areas in developing nations, excess wastewater is disposed of directly, or without effective treatment, into surface water bodies, resulting in their severe degradation; despite the adoption of countermeasures (Ismail and Abed, 2013; Purandara et al., 2011). Water pollution threatens the sustainability of urban systems. Pollution in the Bagmati River

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is a serious concern for the sustainable development of the Kathmandu Valley (Shrestha et al., 2015; Regmi et al., 2014; ICIMOD, 2007). The quantity and quality of river water, particularly during the dry season, is at very alarming levels along most of the river's course through the valley. The water quality problems affecting the Bagmati River include low dissolved oxygen concentrations, bacterial contamination, and metal toxicity. The uncoordinated rapid urban expansion, inadequate wastewater treatment facilities, low levels of awareness, lack of regulations and insufficient adherence to municipal and industrial wastewater generation laws are considered to be the primary reasons for pollution in the Bagmati River. Some sewer lines connect directly to the Bagmati River and its tributaries. Only a few kilometers of uppermost section (high mountain with a catchment area of 17 km^2) is only suitable for drinking water supply. Remaining sections are not used for potable purposes due to greater water quality deterioration. Wastewater management in the valley is limited to the collection of wastewater from different sources through open and underground sewer lines and disposal of untreated wastewater into the rivers (Regmi et al., 2013). Although a number of wastewater treatment plants have been constructed in Kathmandu Valley only one the Guheshwori wastewater treatment plant is currently functional (Table 1). The proposed Kathmandu Valley Wastewater Management Project (KVWMP) of the Government of Nepal is aimed at improving wastewater services in Kathmandu Valley through extensive investment in rehabilitation and expansion of the sewerage network, as well as modernisation and construction of new wastewater treatment plants (ADB, 2013). Construction/rehabilitation of WWTP is expected to help for other uses like irrigation (downstream of Kathmandu valley), recreation etc.

Previous research has been limited to the assessment of current water quality conditions using observation or simulated data. Planning and management activities require the assessment of both current water quality conditions and also future possible scenarios. Assessment of the current situation and future outlook for Bagmati River pollution is intended to explore alternative wastewater management options. The formulation of water quality management strategies requires interdisciplinary analysis of various potential causes of water quality degradation as well as corresponding solutions (Kannel et al., 2007; McIntyre and Wheater, 2004). Mathematical models simulate the pollution of water bodies for likely wastewater production and treatment scenarios (Deksissa et al., 2004; Cox, 2003; Radwan et al., 2003). Computer-based mathematical models can predict water quality. These models may be based on physical data, or a simplified conceptual or empirical approach. Selection of a water quality model depends on data availability, calculation time and intended output variables. Although several models, including QUAL2K and MIKE11, provide detailed insight into water quality conditions in a river system, there are very few models that consider policy-setting issues in detail. The Water Evaluation and Planning (WEAP) model, a decision support system of the Stockholm Environmental Institute, is widely used for integrated water resource planning and management (Sieber and Purkey, 2011). Although the WEAP water quality module does not provide the same level of detail on water quality variables as several other models, it supports scenario formation functionalities, where policy alternatives can be taken into account for current and future conditions. The WEAP hydrology module allows for estimation of rainfall-runoff and pollutant travel from a catchment to water bodies (Ingol-Blanco and McKinney, 2013). Using WEAP model, various scenarios are developed based on variables such as population growth, industrial and commercial activities, land use, the status of treatment plants and sewerage network, and several other factors that can significantly impact wastewater levels. WEAP provides a GIS-based interface to represent graphically wastewater generation and treatment systems. A variety of applications of WEAP for water quality modeling and ecosystem preservation have been reported (Slaughter et al., 2014; Assaf and Saadeh, 2008). Also, WEAP can simulate several conservative water quality variables (which follow exponential decay) as well as non-conservative water quality variables, in addition to pollution generation and removal at different sites which is one of the important reason to use WEAP model in the study. The model with its built-in functions can estimate Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and water temperature; and can be also linked to QUAL2K to simulate far more detailed water quality variables, including nitrogen, phosphorous, sedimentation, algae, pH, and pathogen levels. Comparing simulated water quality values with acceptable (standard) values is helpful for determining if a point or non-non-point source is releasing excessive pollutant. DO and BOD are two widely-used indicators for river pollution (Radwan et al., 2003; Bhutiani and Khanna, 2007; Ingol-Blanco and McKinney, 2013). The volume of confined oxygen in water is characterized by DO values, and excessive disposal of untreated wastewater results in a decrease in DO levels. Although aquatic animals (e.g. fish) can survive at low DO levels (<5 mg/l), prolonged exposure will diminish their normal growth patterns. Usually, water bodies with DO <2 mg/l are considered extremely polluted and result in the die-off of most aquatic animals (Gower, 1980). The BOD is another important pollution indicator and increases along with higher waste concentrations. It is a measure of the dissolved oxygen necessary for microorganisms

Table 1
Existing and planned wastewater treatment plants in Kathmandu Valley.

Wastewater treatment plant	Design capacity, MLD (Million Litre per Day)			Design effluent standard (BOD mg/l)		
	2014	2020	2030	2014	2020	2030
Guheshwori	16.4 (partially working	30.6	30.6	25	15	15
Gokarna	–	0.6	0.6	–	15	15
Sallaghari	2 (virtually not working)	13.1	13.1	–	50	30
Kodku	1.1 (virtually not working)	7.0	11.2	–	50	30
Dhobighat	15.4 (not working)	39.2	81.6	–	50	50

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