学 位 論 文 審 査 の 要 旨

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学 位 論 文 題 名

An integrated approach to evaluate challenges and opportunities to address water resource management issues in Can Tho City, Vietnam

(ベトナム、カントー市における水資源管理問題への取り組みのための課題と機会の評価の統合的アプローチ)

Rapid industrial urbanization, land-use change, and climate change are the key drivers of complex water pollution in particular and integrated water resource management (IWRM) in general globally. Being no exception, Can Tho City is currently experiencing water stress, especially surface water quality (SWQ), driven by rapid global changes. Multivariate analytical techniques, Water Evaluation and Planning (WEAP) tool, and systematic review was used in this study to thoroughly assess the city's present, past, and future SWQ status under rapid land-use and climate change. The last part of the thesis focuses on the water governance (WG) issues to further strengthen science-policy interface and proposes mitigation and adaptive measures to improve SWQ, WG, and IWRM in Asian cities including Can Tho City in Vietnam. 145 publications related to WG in Asian region were thoroughly studied in this research to develop a WG framework for the study area.

The SWQ dataset with 14 parameters at 73 sampling sites were collected in this study. Various physiochemical parameters were assessed. The average levels of biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), total coliform (TC), turbidity, total suspended solids (TSS), and phosphate (PO_4^{3-}) exceeded the permissible national levels. Spatially, cluster analysis (CA) divided the city's river basin into three different zones (mixed urban-industrial, agricultural, and mixed urban-rural zones). Principal component/factor analysis (PCA/FA) identified their key SWQ pollution sources, mainly related to domestic wastewater, industrial effluents, agriculture runoff, soil erosion, and severe droughts. Discriminant analysis (DA) also explored that COD, DO, nitrate (NO_3^-), PO_4^{3-}, and turbidity were the key parameters discriminating SWQ in the city among seasons and land-use zones. The temporally-analyzed results from Weighted Arithmetic Water Quality Index (WAWQI) estimation revealed the deterioration of SWQ conditions, whereby, the total polluted monitoring sites of the city increased from 29% in 2013 to 51% in 2019, mainly due to the expansion in built-up and industrial land areas, agriculture runoff, and droughts. Regarding the city's future SWQ simulation, the Business as Usual (BAU) scenario; scenarios with measures (WMs) i.e., wastewater treatment plants (WWTPs) for treating 75% (WM75) and 100% (WM100) of total future wastewater generated; and the optimistic scenario (WM_Opt.

i.e., WM100 + additional treatment plants for river water (RWTPs)), were applied. As simulated, the average values of BOD, TC, NO_3^-, and PO_4^{3-} in the wet season of 2030 under BAU scenario will be increased by 16.01%, 40.85%, 30.49%, and 20.22%, respectively as compared to those of the current year. In the dry season, these rates will be increased by 27.80%, 65.94%, 31.05%, and 20.64%, respectively. Under WM75 and WM100, although SWQ was improved but did not reach the desired limits, especially for BOD and PO_4^{3-} levels. However, under the WM_Opt., the average values of BOD and PO_4^{3-} will be significantly declined by 76.53% and 63.96%, respectively as compared to the current situation and achieve SWQ under Class-A.

Compared to existing WWTPs, the robust IWRM including an effective WG is considered a more effective solution for sustaining the acceptable status of the future SWQ. WG in the Asian region including Vietnam was systematically reviewed to explore the governance challenges and measures to improve IWRM. As reviewed, the countries in Southeast Asian, South Asian and East Asian regions were the main hotspots to study WG-related issues, mainly due to highest population, abundant water resources, and complex WG issues. Noticeably, transboundary water, water quality, irrigation, and hydropower management were considered as key drivers of WG framework in Asian region, mainly due to a lack of joint agreements in the cross-border river basins. Moreover, inadequate legal and institutional framework, limited stakeholder engagement, poor coordination and cooperation, and unstable politics and power were the main reasons behind the complex WG in Asian region. To analyze these issues, diverse frameworks were used, which were mostly rooted in the Ostrom's work. Besides, the OCED's framework has been also frequently utilized in recent years. Similarly, a wide range of governance elements was included in these frameworks for analysis. Legal and institutional arrangements, stakeholder engagement, and cooperation and coordination were most-discussed elements reflecting the fact that inadequate laws, institutions, stakeholder cooperation were chronic governance challenges in this continent. Remarkably, the number of elements analyzed had increased from six in the early 2000s to ten after 2015. Finally, an optimal framework was proposed for assessing Asian WG; and its governance challenges as well as key recommendations were given. Overall, the findings of this study will help local policymakers to thoroughly review, assess, and adjust existing water policies and master plans towards achieving the city's desired SWQ standard as well as a robust and comprehensive IWRM. Besides, this study also provides useful knowledge for local planners and technical staff to enhance their capacity in applying advanced approaches and tools for evaluating water quality at their respective watershed levels.

The outcomes of this thesis are policy-relevant and aligned well with current population-urban-water nexus approach to make urban center more resilient to climate change. This research demonstrates the importance of water quality simulations and future scenarios as well as water governance, which can help city planners to minimize the water quality related risk in the near future. This research can also provide essential knowledge in planning relevant management policies and strategies in a timely manner to achieve SDGs goal number 6.

The examination committee recognized that this thesis presents important findings in the current research related to water resource management in data scarce region. In addition to the excellent academic knowledge in the research, his academic records throughout the Ph. D. course was good. Based on these evidences, the committee reached to the conclusion that Nguyen Hong Duc is eligible for the degree of Doctor of Philosophy (Environmental Science).