学 位 論 文 内 容 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 pollution (SWQ), driven by rapid global changes. Using multivariate analytical techniques, the Water Evaluation and Planning (WEAP) tool, and systematical review, this thesis thoroughly assesses the city's past, current, and future SWQ statuses under rapid land-use and climate changes; and later 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 these countries including Vietnam and its developing Can Tho City. The SWQ dataset with 14 parameters at 73 sampling sites in the city and 145 Asian WG publications were assessed and analyzed.

As assessed, 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) was 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, farming 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, farming 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 plants, the robust IWRM including an effective WG is considered a more effective solution for sustaining the acceptable status of the future SWQ. Thus, due to a lack of the Vietnamese WG information, WG in the Asian developing countries comprising Vietnam was systematically reviewed to explore their governance challenges and measures to improve IWRM. As reviewed, geographically, the countries in SEA, SA, and EA regions were the main hotspots for studying WG-related issues, mainly due to these regions' unique characteristics within Asia such as the largest areas and highest population, abundant water resources, and complex WG issues. Noticeably, transboundary water, water quality, irrigation, and hydropower management were considered key drivers of challenging the Asian WG, mainly due to a lack of joint agreements in the cross-border river basins there. 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 this continent's countries as well as between them. 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 analyzing. Legal and institutional arrangements, stakeholder engagement, and cooperation and coordination were respectively the 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 obtained findings 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, the thesis 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. Moreover, this thesis will also aid the city in designing relevant management policies and strategies in a timely and appropriate manner to achieve its SDGs, particularly SDG 6.

Keywords: Surface water quality, spatiotemporal variations, multivariate statistical approach, water quality index, water quality modeling, river water and wastewater treatment, integrated water resource management, water governance, governance challenges, the Asian developing countries , Can Tho City, Vietnam.