Eutrophication risk assessment in the Saigon – Dong Nai Rivers (Southern Vietnam)

Évaluation du risque d'eutrophisation dans les rivières Saigon – Dong Nai (Sud Vietnam)

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RÉSUMÉ

Sur la base d'un suivi sur deux ans et demi (Juillet 2015 – décembre 2017), nous proposons une évaluation du risque d'eutrophisation d'une rivière tidale (la rivière Saigon) impactée par les rejets de la mégalopole d'Ho Chi Minh Ville (HCMV, plus de 8.4 millions d'habitants). Pour cette évaluation, nous nous basons sur les concentrations en nutriments dissous et totaux (phosphore, azote et silice), les matières en suspensions (MES), en oxygène dissous, en chlorophylle *a* et sur l'abondance et l'identification des espèces algales. Quatre sites de mesures ont été choisis sur les deux rivières Saigon et Dong Nai pour mettre en évidence l'impact d'HCMV sur la qualité des eaux par rapport à aux points de mesure de référence en amont de la ville. Les valeurs les plus fortes de MES, nutriments, chlorophylle *a* et abondance phytoplanctonique sont observées au niveau du site localisé au cœur d'HCMV. Au niveau de ce site, les diatomées dominent les espèces phytoplanctoniques. Au niveau de la rivière Dong Nai, dans laquelle se jette la rivière Saigon en aval d'HCMV, les Cyanobactéries sont plus présentes mais avec des abondances moindres par rapport au site d'HCMV. Nous mettons en évidence que l'impact d'HCMV via les rejets des eaux usées non traitées contribue à l'enrichissement en nutriments de la rivière Saigon et conduit à des développements algaux et des très faibles oxygénations typiques des milieux eutrophes.

ABSTRACT

Based on a bi-monthly monitoring during two years and a half (July 2015 – December 2017), we assess the eutrophication state of a tidal riverine system impacted by a developing megacity, Ho Chi Minh City (HCMC; more than 8.4 million inhabitants). Total Suspended Sediment (TSS), nutrients (dissolved and total Nitrogen, Phosphorus and Silica), Dissolved Oxygen (DO) and phytoplankton biomass (Chlorophyll a) and abundance (counting and species identification) are used for the assessment. Four monitoring sites were selected: one site on the Saigon River upstream (Phu Cuong) and one site on the Dong Nai River upstream (Hoa An) which represent both the reference water quality status before HCMC. One monitoring site in the city center (Bach Dang) highlights the impact of HCMC on the water quality of Saigon River. The last site downstream the confluence between the two rivers (Binh Khanh) allows evaluating the global impact of HCMC to the estuarine waters. We measured the highest values of TSS, nutrients, phytoplankton abundance and biomass at Bach Dang station in the city center. Diatoms species and Cyanobacteria dominate in the Saigon River and in the in Dong Nai River respectively. We highlight that untreated domestic waste waters release lead to the degradation of Saigon River's water quality with very high level of algal biomass and hypoxia condition typical of eutrophic system.

KEY WORDS

Water quality, nutrients, phytoplankton, eutrophication risk, megacity

1 INTRODUCTION

Ho Chi Minh City (HCMC, up to 8.4 million inhabitants), the economic capital of Vietnam, is one of the most dynamic metropolitan areas in the South East of Asia. The 10% increase of its gross domestic products and 3% increase of urban growth per year over the last ten years (e.g. population density of 3719 persons per km² in 2012; GSO 2014) induced rapid economic, industrial and domestic developments. Those increases have serious consequences on the river crossing the city, the Saigon River (Strady et al 2017). HCMC does not have adapted collections and water treatments in line with requirements. According to the main wastewater treatment plant managers in District 7, less than 10% of domestic water are treated before being discharged directly the hydrographic network. In addition, industrial activities, with about 30 000 small industries and more than 800 large factories in 15 industrial zones, do not have adequate and effective wastewater treatment systems (Coulthart et al., 2006). The assessment of the water quality is one of the major concerns for local authorities with the presence downstream of HCMC of a large aquaculture production area within the protected area of Can Gio Mangrove (area classified "Biosphere Reserve" by UNESCO).

Based on a bimonthly monitoring program realized in the framework of the project Saigon : La Ville et le Fleuve funded by AURA Region (2015-2017), the objectives of this study are to analyze the spatial and seasonal patterns of water quality to evaluate the impact of HCMC and assess eutrophic status of the Saigon and Dong Nai Rivers.

2 MATERIAL AND METHODS

2.1 Study site

The Saigon River, located in Southern Vietnam, is about 250 km long with a basin area of 4717 km² against about 40 000 km² for the Dong Nai River basin (Fig.1). Two dams (Dau Tieng and Tri An reservoirs) influence the hydrology of both rivers. The Saigon River flows through HCMC and is connected to urban canals receiving wastewaters. Downstream HCMC, the Saigon River joins the Dong Nai River to form the estuarine area. It then flows through the Can Gio mangrove before to reach the coastal area (East Sea). The regional climate is tropical with monsoon seasons: a wet season from May to November and a dry season from December to April. The Saigon and Dong Nai Rivers are influenced by asymmetric semi-diurnal tides, which induces alternating river flow direction and salty water intrusion upward HCMC especially during the dry season.

2.2 Sampling strategy and analysis

A bi-monthly monitoring was undertaken from July 2015 to December 2017 to investigate the spatial and temporal evolution of physico-chemical parameters, nutrients and phytoplankton in order to assess the eutrophication state of the Saigon and Dong Nai Rivers. Four sites including Phu Cuong and Hoa An (upstream of the two rivers), Bach Dang (in the city center of HCMC) and Binh Khanh (downstream of the confluence between the two rivers) were chosen (Fig. 1). This sampling strategy allows to assess the impact of HCMC and to compare the water quality between the two rivers. The samples were analyzed *in situ* for physico-chemical parameters (e.g. pH, conductivity, salinity, temperature, dissolved oxygen) and in laboratory for total and dissolved nutrients (phosphorus, nitrogen and silica) and Chlorophyll a. All measurements were realized by spectrocolorimetric method using CARE laboratory facilities in Vietnam. In addition algal species composition was identified and the abundance estimated through direct microscopic counting.

3 RESULTS AND DISCUSSION

Bach Dang in the city center presents the highest values of TSS (mean annual values of 90 ± 59 mg/L), and nutrient concentrations especially for Total Phosphorus (mean annual value of 0.27 ± 0.16 mgP/L), and Total Nitrogen (mean annual value of 3.38 ± 0.91 mgN/L), which indicates an important input of nutrients into the Saigon River. As a consequence of this nutrients enrichment, the chlorophyll *a* concentration is high with extreme value up to 148 µg Chl-a/L and generally above the eutrophication limit during the dry season (i.e above 25 µg Chl-a/L). The level of DO is also extremely low most of the time (< 2 mgO_2/L) indicating a probable intense activity of mineralization. Maximum phytoplankton abundance is observable from the end of March – end of April (Hoa An and Phu Cuong), end of February – end of April (Bach Dang), and beginning of February – end of March (Binh Khanh). The phytoplankton abundance was higher at Bach Dang (more than 2 500 10^3 ind/L), much lower at Phu Cuong and Hoa An (about 400 10^3 ind/L), and the lowest at Binh Khanh (less than 40 10^3 ind/L). We found that phytoplankton abundance was closely correlated with chlorophyll *a*

concentration (R^2 = 89.4%). The phytoplankton composition was dominated by Diatoms species (e.g. *Leptocylindrus, Cyclotella* and *Aulacoseira* at Phu Cuong, Bach Dang and Binh Khanh) and by Cyanobacteria (e.g. *Microcystis, Cylindrospermopsis* and *Anabaena* at Hoa An) among others (e.g. green algae, euglenoids, dinoflagellates and chrysophytes) (Fig. 1). The NH_4^+ and PO_4^{3-} concentrations at the stations were favorable for development of phytoplankton and dissolved silica concentration (0.5 g/L) was never limiting for growth of Diatoms. These results highlight a clear eutrophic status of the Saigon River located at Bach Dang which should be taken into account by stakeholders to plan the collection and the treatments of urban waste waters. The findings from the present study are important and could be useful for the aquatic environmental and ecological protection of the Saigon and Dong Nai Rivers.

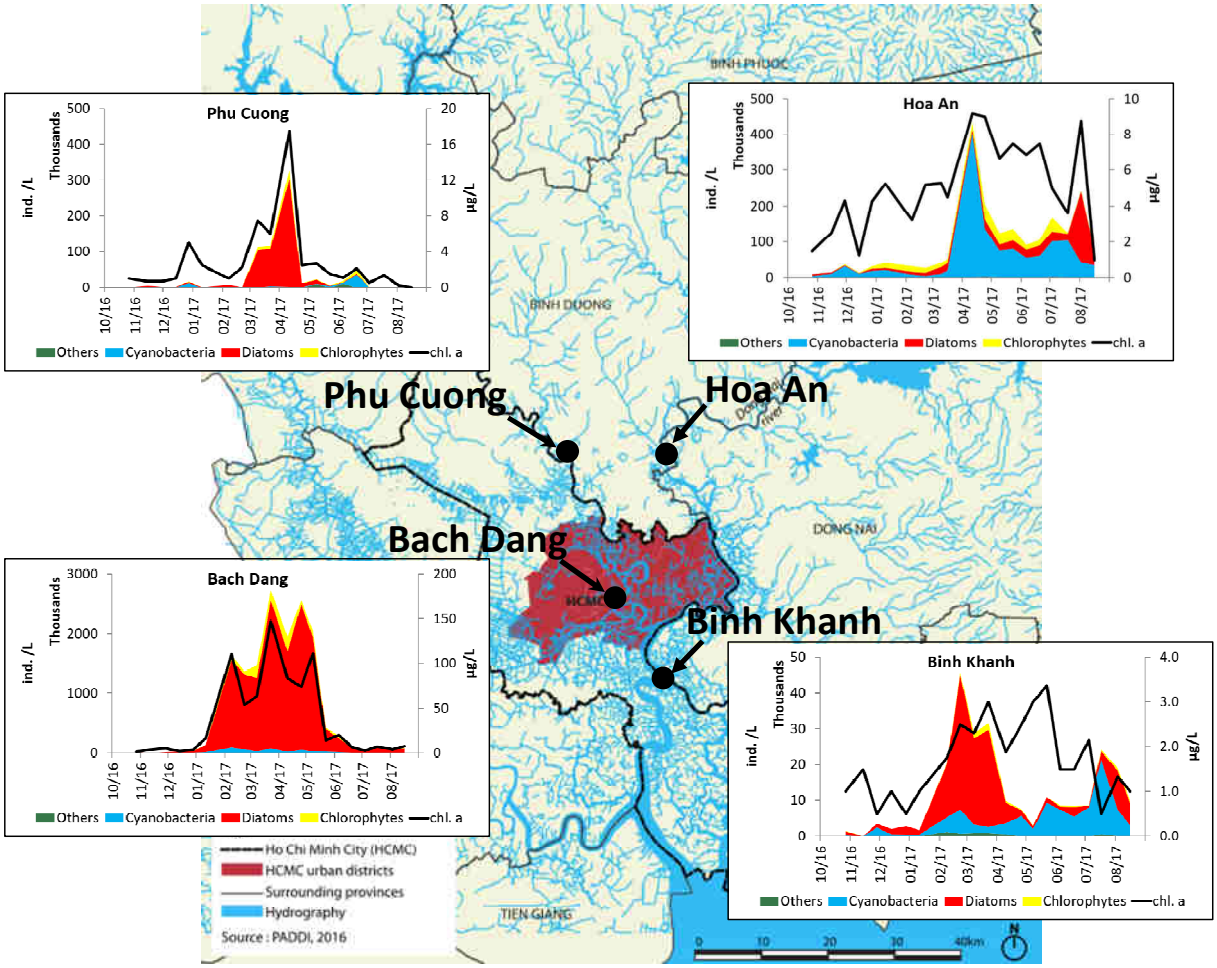

Figure 1. Map of the Saigon Dong Nai Rivers and location of sampling sites. Seasonal variation of phytoplankton abundance and diversity and chloropyl a concentrations at four sampling sites (target period of October 2016-September 2017)

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