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Water quality of the Red River system in the period 2012 - 2013

Chất lượng nước hệ thống sông Hồng giai đoạn 2012 - 2013

Short communication

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Few data are available on the quality of Red river water that is used for multi-purposes, including for domestic water demand in some rural areas. This paper presents the observation results of the Red River water quality in two years 2012 and 2013. The monitoring results showed that the average concentrations of nutrients (N, P) were still far lower than the allowed value of the Vietnamese standard limits for surface water quality (QCVN 08:2008/BTNMT, column A2). Due to the impoundment of two big dams in the Da tributary, the suspended solids contents in river water decreased remarkably. The dissolved heavy metal (DHM) concentrations varied in a high range: Cu: 10 – 80 μg.l^{-1}; Zn: 2 – 88 μg.l^{-1}; Cr: 0.2 – 5.1 μg.l^{-1}; Pb: 2 - 107 μg.l^{-1}; Cd: 2 – 12 μg.l^{-1}; Mn: 2 - 35 μg.l^{-1}; and Fe: 160 – 2370 μg.l^{-1}. Most of the mean values of DHM were lower than the allowed values of the QCVN 08:2008/BTNMT, but at several points of time, several DHM (e.g. Fe, Cd, Pb) contents exceeded the allowed values. The Total Coliform (TC) and Fecal Coliform (FC) densities varied in a high range: TC: 23 to 13,000MPN.100ml^{-1} and FC: 0 to 1,600MPN.100ml^{-1} and they exceeded the allowed values QCVN 08:2008/BTNMT at several points observed. The dissolved organic carbon (DOC) contents were in low level and the particulate organic carbon (POC) content mainly derived from soil organic leaching and erosion in the basin. The results underlined the need for regularly monitoring the river water quality, and there should be some effective solutions to manage and treat the waste sources in order to provide safe water for different actual purposes use in the Red River basin.

Rất ít số liệu sẵn có về chất lượng nước sông Hồng, dòng sông được sử dụng cho nhiều mục đích, bao gồm cả cung cấp nước sinh hoạt ở một số vùng nông thôn. Bài báo trình bày các kết quả quan trắc chất lượng nước sông Hồng trong hai năm 2012 và 2013. Kết quả quan trắc cho thấy chất dinh dưỡng (N, P) thấp xa so với giới hạn cho phép của tiêu chuẩn Việt Nam về chất lượng nước mặt (QCVN 08: 2008/BTNMT cột A2). Do có hai hồ chứa trên sông Đà, hàm lượng chất rắn lơ lửng trong nước sông giảm đáng kể. Các kim loại nặng hòa tan (DHM) có hàm lượng dao động trong khoảng rộng: Cu: 10-80 μg.l^{-1}; Zn: 2-88 μg.l^{-1}; Cr: 0,2-5,1 μg.l^{-1}; Pb: 2-107 μg.l^{-1}; Cd: 2-12 μg.l^{-1}; Mn: 2-35 μg.l^{-1}; và Fe: 160 - 2370 μg.l^{-1}. Hầu hết các giá trị trung bình của DHM thấp hơn giá trị cho phép của quy chuẩn QCVN 08: 2008/BTNMT, tuy nhiên, tại một số thời điểm, một số DHM (ví dụ Fe, Cd, Pb) có hàm lượng vượt quá giới hạn cho phép. Mật độ tổng coliform (TC) và coliform phân (FC) dao động trong khoảng rộng: TC: 23 đến 13,000MPN.100ml^{-1} và FC: 0 đến 1,600MPN.100ml^{-1} và tại một số thời điểm mật độ TC và FC vượt giá trị cho phép của Quy chuẩn QCVN 08:2008/BTNMT. Hàm lượng cabon hữu cơ hòa tan (DOC) ở mức thấp, và hàm lượng cacbon hữu cơ dạng không tan (POC) chủ yếu có nguồn gốc từ đất rửa trôi và xói mòn trong lưu vực. Kết quả quan trắc nhấn mạnh nhu cầu giám sát thường xuyên chất lượng nước sông, và nên có các giải pháp hiệu quả để quản lý và xử lý các nguồn gây ô nhiễm trong lưu vực nhằm cung cấp nước sạch cho các mục đích sử dụng nước sông Hồng như hiện nay.

Keywords: water quality, Red River, Vietnam, human impact, non-point source, point source

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1. Introduction

In recent years, human perturbations of agricultural, domestic and industrial origins have largely impacted on structure and function of their environment, especially on water environment. The Red River is a good example of a Southeast Asian river system, affected by human activities.

The Red river (basin area: 156 451 km²) plays an important role in economic and social development in the North Vietnam. The river water sources in Vietnam are significantly used for agricultural irrigation, for industries in the provinces of its upstream basin and for domestic demand in country-village (Nguyen et al., 1995). Whereas the benefits of this river are clearly identified in Vietnam, its role in China has not been clearly recognised, perhaps less important because of its morpho-geography unfavourable to human activities (94% of hills and mountains in Yunnan province (Chinadata, 1998).

In parallel with the economic development in the basin, the water pollution has been a great concern. However, few data are available on the Red River water quality, both in China and in Vietnam, excepted those collected at the outlet of the rivers in the delta area (Nguyen, 1984; Chu et al., 2014) or some sparse observations in order to provide water river for the agricultural and industrial production (Truong, 2002). For filling this gap of knowledge, we organized sampling campaigns at the outlet of each three sub-basins Da, Lo and Thao and in the main branch of the Red River over two annual cycles (2012 - 2013). Different variables of water quality were observed in order to better characterise the water quality of the Red River.

2. Methodology

2.1. Study area

Land use is very diverse from upstream sub-basins and the delta area. Industrial crops dominate (58.1%) in the Lo basin, forests (74.4%) in the Da basin, paddy rice fields (66.3%) in the delta area, whereas the Thao basin is characterized by a larger diversity of land use (forest: 54.2%; paddy rice fields: 18.7%; industrial crops: 12.8%).

The hydrological regime is of monsoon type, with higher discharges in summer. The contribution of the Da River to the discharge of the Red River is the highest. The water discharge at four gauging stations Yen Bai, Vu Quang, Hoa Binh and Hanoi (Figure 1) in two years 2012 – 2013 were not significantly different, averaged 530; 1220; 1470 and 1910 m^3/s respectively.

2.2 Water sampling and analysis

The monthly sampling campaigns were conducted from January 2012 to December 2013 at four gauging stations (Figure 1).

Water quality checker, model WQC-22A (TOA, Japan), was used to measure physical-chemical variables such as temperature, pH, conductivity and dissolved oxygen (DO). Water samples were sequentially filtered through Whatman GF/F paper for analyzing dissolved substances: nitrogen (nitrite, nitrate and ammonia); phosphorus (phosphate); silica (DSi); organic carbon (DOC) and heavy metals.

Figure 1. The Red River system and four gauging stations

Nutrients (N, P, Si) and chlorophyll a were spectrophotometrically measured by an UV-VIS V-630 (JASCO, Japan) by different methods described in Le et al., (2005). DOC was determined using a TOC-V_E (Shimadzu, Japan). Dissolved heavy metals (DHM) such as Cu, Zn, Cr, Pb, Cd, Mn and Fe) were spectrophotometrically determined by the Vietnamese standard methods: Cu: TCVN 4572 – 88; Zn: TCVN 4575 – 88; Cr: TCVN 6658 – 2000; Cd: TCVN 2664 – 78; Pb: TCVN 4573 – 88; Mn: TCVN 6002 – 1995 and Fe: TCVN 6177 - 1996. Particulate organic carbon (POC) was analyzed using a device LECO CS 125. Total coliform TC and fecal coliform FC densities were numbered by the Vietnamese standards TCVN 6187-2: 1996.

3. Results and discussion

3.1 Physico-chemical variables

Physico-chemical variables of the Red River system were monthly observed during two years 2012 and 2013. The results (table 1) showed that the water temperature was in the range from 14.4 to 35.0 °C, the mean value averaging 25.4^{0}C. The conductivity varied with the median value of 182 $\mu S.cm^{-1}$. The pH varied from 6.0 – 8.5 with an average value of 7.8. The DO concentrations varied from 2.1 to 7.2 mg $O_2.l^{-1}$. The suspended solids varied much within 4 stations: the highest value at Yen Bai (119 $mg.l^{-1}$) and the lowest value at Hoa Binh (11 $mg.l^{-1}$) where two big dams are impounded. The concentration of suspended solids at Hoa Binh station was much lower than previous time when there was only Hoa Binh reservoir, e.g. (Le et al., 2007).

Table 1. Physico-chemical variables of the Red River during the years 2012 – 2013

Sites	Temperature, ^{0}C	pH -	Conductivity, µS.cm^{-1}	DO mg.l^{-1}	SS, mg.l^{-1}
Yen Bai	25.9 14.4-32.0	7.9 6.8-8.5	178 136 -242	3.8 2.6-6.1	119 20-376
Hoa Binh	25.8 15.0-33.0	7.7 6.8-8.3	168 133-204	3.7 1.9-5.6	11 2-37
Vu Quang	25.8 13.8-35.0	7.8 6.8-8.5	202 156-253	3.8 1.9-5.6	24 4-90
Hanoi	25 15.7-33.2	7.8 6.0-8.5	181 127-292	4.0 2.1-7.2	55 18-153
QCVN 08:2008 /BTNMT, A2	-	**6.0 -8.5**	-	**≥5**	**30**

3.2 Nutrients (N, P, Si) and algal pigments

3.2.1 Nitrogen

The nitrate concentrations varied from 0.16 – 0.96 mgN-NO_3.l^{-1} and averaged 0.58 mgN-NO_3.l^{-1} at four sites (table 2). The values found for nitrate were still far below the Vietnamese Standards limits for surface water quality, QCVN 08:2008/BTNMT (5 mgN-NO_3.l^{-1}).

Table 2. Nutrients and chlorophyll a contents (average, minimal - maximal values) of the Red River during the years 2012 – 2013

Sites	NO_3 mgN.l^{-1}	NH_4 mgN.l^{-1}	PO_4 mgP.l^{-1}	Ptot mgP.l^{-1}	DSi mg.l^{-1}	Chl *a* µg.l^{-1}
Yen Bai	0.69 0.26- 0.96	0.09 0.02- 0.35	0.038 0.008- 0.281	0.27 0.06- 0.59	6.0 3.7- 7.5	1.63 0.20- 4.80
Hoa Binh	0.43 0.16- 0.70	0.06 0.02- 0.22	0.024 0.003- 0.085	0.08 0.01- 0.27	6.0 5.1- 7.2	1.66 0.20- 3.30
Vu Quang	0.64 0.23- 0.86	0.10 0.02- 0.41	0.035 0.0003 -0.189	0.11 0.01- 0.23	5.2 3.8- 6.2	1.77 0.08- 3.28
Hanoi	0.58 0.19- 0.87	0.10 0.01- 0.30	0.046 0.004- 0.194	0.17 0.04- 0.53	5.4 4.5- 6.9	1.97 0.08- 4.67
QCVN 08:2008/ BTNM, A2	5	0.2	0.2	-	-	-

Ammonium concentrations were low, varied from 0.01 – 0.41 mgN-NH_4.l^{-1} and averaged 0.09 mgN-NH_4.l^{-1} at four sampling sites. Contrary to the nitrate concentrations that tended to increase during rainy seasons under leaching from the agricultural lands, ammonium concentrations in the Red River tended to show a dilution.

Considering the proportion of nitrate, nitrite and ammonium in total inorganic nitrogen, it appeared that nitrate was, in proportion, the dominant form, around 83 %. The proportion in nitrite remained very low ($\leq$ 2 %).

3.2.2 Phosphate and total phosphorus (Ptot)

Phosphate concentrations varied from 0.002 – 0.28 mgP-PO_4.l^{-1} and averaged 0.04 mgP-PO_4.l^{-1} at four sites. These low levels might be a limiting factor for least growth of algal at certain periods, depending on the seasonal variations. However, Ptot concentrations were much higher, from 0.01 - 0.59 mgP.l^{-1}, averaging 0.16 mgP.l^{-1}. The Ptot concentration seemed higher in rainy season than in dry season, indicating that phosphorus is more issued from diffusion than from point sources.

3.2.3 Dissolved silica (DSi) and algal pigments

DSi concentrations in rivers mainly originate from rock weathering, and therefore depend on the lithology (Meybeck, 1986). The lithological composition of the Red River watershed is dominated by sedimentary rocks, with about half of carbonated rocks. DSi concentration averaged 5.5 mgSi.l^{-1} at four sites.

Total chlorophyll *a* (Chl *a*, µg.l^{-1}) contents were relatively low (table 2), which may be influenced by high suspended solid and water flow.

3.3 Heavy metals

DHM concentrations in the Red River water at four gauging stations were monthly observed during the year 2012 in the framework of the INPC one-year-project. The results showed that the DHM concentrations varied in a high range (with the mean value): Cu: 10 – 80 (31) µg.l^{-1}; Zn: 2 – 88 (31) µg.l^{-1}; Cr: 0.2 – 5.1 (2.0) µg.l^{-1}; Pb: 2 - 107 (15µg/l); Cd: 2 – 12 (5.5) µg.l^{-1}; Fe: 160 – 2370 (950) µg.l^{-1}. No clear seasonal variation of DHM concentrations was observed, which may reflect the complex pollution source of heavy metals.

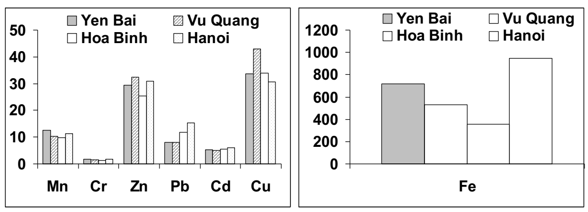

Figure 2. Average values (µg/l) of DHM contents at four gauging stations of the Red River system in 2012

These average concentrations of DHM of the Red River water were higher than the average values of the World Rivers, proposed by Viersa et al., (2009): Cu: 1.48µg.l^{-1}; Zn: 0.60µg.l^{-1}; Cr: 0.70µg.l^{-1}; Pb: 0.08µg.l^{-1}; Cd: 0.08µg.l^{-1}; Mn: 34µg.l^{-1}; Fe: 66µg.l^{-1} except the value of Mn; and these values were much lower than those in rivers impacted by urban or industrial zones.

Almost all values of DHM contents were lower than the ones of the QCVN 08:2008/BTNMT. However, at several time during the observation period, the contents of some DHM such as Fe, Cd and Pb exceeded the Vietnamese standard limits and values proposed by WHO (2011) (Cr ≤ 50µg.l^{-1}; Cd ≤ 5µg.l^{-1}; Mn ≤ 50µg.l^{-1}; Pb ≤ 25µg.l^{-1}). The high DHM in the Red River water can influence indirectly and/or directly to the human health due to the river water use as drinking water, irrigation and aquaculture.

3.4 Coliforms

TC and FC of the Red River system were observed from January to December 2013 in the framework of the NAFOSED project (for L.T.P.Q), which started in 2013. TC and FC densities varied in a high range: TC from 23 to 13,000MPN.100ml^{-1} with an average value of 1,765 MPN.100ml^{-1}. The FC values ranged from 0 to 1,600MPN.100ml^{-1} with an average value of 191 MPN.100ml^{-1}. The higher values of TC and FC were found in the main axes of the Red River (in Yen Bai and Hanoi stations) (Figure 3).

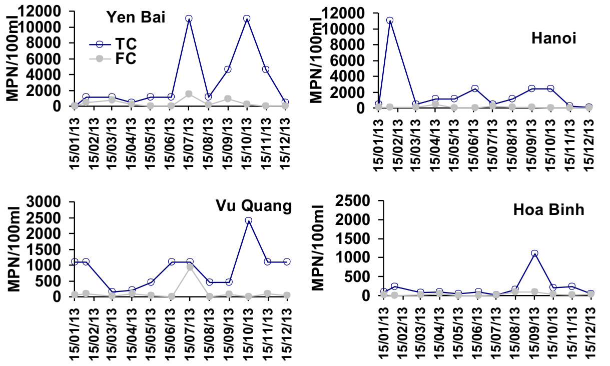

Figure 3. TC and FC densities at four gauging stations of the Red River system in 2013

These values were closed to the average values reported from previous studies (ICEM, 2007; Truong, 2012) for some sites of the Red River but much lower than the average values from urban rivers e.g. the Nhue river in Hanoi city (TC: 106,600 MPN.100ml^{-1}; FC: 49,200 MPN.100ml^{-1}); and were lower than the ones of some rivers in the World such as the Hindon river (India) (Yadav & Mishra, 2014), or the Danube river (Romania) (Ajeagah et al., 2012).

Almost all TC and FC values of the Red River water were lower than the allowed limits given in QCVN 08-2008 but at some observed time, they exceeded from 1.5 to 2.5 times over the allowed limits. The high TC and FC densities in the Red River system may influence indirectly and/or directly to the human health due to the river water use as drinking water, irrigation and aquaculture. As known, most of coliforms are non-pathogenic, but some strains can cause diseases such as diarrhea, dysentery, urinary tract infections, hepatitis, bronchitis, pleurisy etc.

3.5 Organic matters

The DOC values were from 0.2 to 4.6 mgC.l^{-1}, averaging 1.1 mgC.l^{-1} at four sites (Table 3). These values might seem low compared with the figures for wet tropical regions (8 mgC.l^{-1}) proposed by Meybeck (1988), but probably reflects the absence of alluvial forests in the Red River basin. The POC contents varied from 0.2 to 3.7 mgC.l^{-1}, averaged 1.2 mgC.l^{-1} at four sites. These values are lower than those proposed by Ittekkot and Laane (2002) for the different ranges of river suspended solid concentration. The POC/Chl a ratios ranged from 174 to 4872 (Table 3), averaging 1300 for the whole Red River that were much greater than the range of values for the typical phytoplankton development in river water (POC/Chl a ratio: 30 – 100 mgC.mgChl a^{-1} (Abril et al., 2002). This result suggests that POC in the water of the Red River mainly derived from soil organic leaching and erosion in the basin.

Table 3. DOC and POC contents (average, minimal - maximal values) of the Red River system during the year 2013

Sites	DOC mgC.l^{-1}	POC mgC.l^{-1}	POC/Chl a mgC.mgChl a^{-1}
Yen Bai	1.57 0.20-4.31	1.74 0.76-3.72	1720 500 -4872
Hoa Binh	1.02 0.17-3.38	0.56 0.20-1.12	646 174 -1349
Vu Quang	1.15 0.33-4.56	1.07 0.44-1.64	1430 323-4250
Hanoi	1.45 0.22-2.28	1.27 0.92-1.72	1236 881-1777

4. Conclusions

The monitoring results showed that the average concentrations of nutrients (N, P) were still far lower than the allowed value of the Vietnamese standard limits for surface water quality, QCVN 08:2008/BTNMT. Due to the impoundment of two big dams in the Da tributary, the suspended solids contents decreased remarkably. The dissolved heavy metal (DHM) concentrations varied in a high range but only for several time, some DHM (e.g. Fe, Cd, Pb) contents exceeded the allowed values of the QCVN 08:2008/BTNMT. The TC and FC densities also varied in a high range and at several points observed, they exceeded the allowed values. The DOC contents were in low level and the POC content reflected its source from soil organic leaching and erosion in the basin.

The high DHM, TC and FC values in the Red River water at several points observed can influence indirectly and/or directly the human health due to the river water use as drinking water, irrigation and aquaculture. Thus, the results underlined the need for more frequently and systematically monitoring of the river water quality. And there should be some effective solutions to manage and treat the waste sources in order to provide safe water for different purposes of river water use as actual in the Red River basin.

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