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Assessment of the Water Quality of the Nhue River in Vietnam and its Suitability for Irrigation Water

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The Nhue River in Vietnam is the main source of irrigation water for suburban agricultural land and fish farm. Wastewater from the industrial plants located along these rivers has been discharged, which has degraded the water quality of the rivers. The present paper describes the chemical properties of water from the river focusing on heavy metal pollution and the suitability of water quality for irrigation. Water from the river was heavily polluted with heavy metals such as Pb, Cu, Zn, Cr, Cd and Ni. Dissolved oxygen, COD, and total suspended solids, and the concentrations of all heavy metals exceeded the Vietnamese standard for surface water quality in all investigated sites. The concentrations of some heavy metals such as Cu, Cd, Cr and Ni were over the internationally recommended WHO maximum limits for irrigation water. A wide variation in heavy metal concentration of water due to metal types is the result of wastewater discharged from different industrial sources.

Key words: heavy metals, industry, irrigation, stream water

INTRODUCTION

There are various regulations and standards in Vietnam to control the pollutants discharged from industrial plants, but the implementation of these is lacking. Water pollution in the urban rivers and channels of Hanoi, Vietnam, caused by untreated domestic and industrial waste has been serious, and the pollutants discharged into the rivers have damaged aquaculture in a downstream area (Kikuchi *et al*., 2009). High concentrations of several toxic heavy metals such as Cr and Hg have been detected in effluents from paper and metal processing factories (Kikuchi *et al*., 2009).

Industrial wastewater has been discharged to the Nhue River in Viet Nam without proper treatment, which has given adverse impact on the water quality of the river system, causing major concerns from farmers. However, much attention has not been paid to how the water pollution of these rivers has affected on agricultural land and crops through irrigation, and very few studies on the water quality of these rivers have been conducted (Luong *et al*., 2003; Nguyen *et al*., 2007)

Water pollution is harmful not only to fish breeding and agricultural products, but also to public health in surrounding areas. Of the pollutants, heavy metals can endanger public health by being incorporated into food chain. Heavy metals are not biodegradable and tend to accumulate in the sediments of waterways in association with organic and inorganic matter in the sediments.

The Nhue River stemming from the Red River through the Lien Mac sluice, flows through several western districts of Hanoi such as Cau Giay, Tu Liem and Thanh Tri, further runs through Ha Dong Town, Hoai Duc, Thuong Tin, Thanh Oai, Phu Xuyen Districts and finally joins the Day River near the town of Phu Ly, in the Ha Nam Province. The Nhue River with the catchments area of 1,070 km^2 and 40 km long, branches from the Red River about 11 km to the north west of Hanoi, and joins the To Lich and Kim Nguu River system some 20 km downstream of Hanoi (Trinh *et al*., 2007). The mean inflow to the Nhue River from the Red River is 26 m^3/s. It also receives around 5.8 m^3/s of untreated wastewater from the To Lich and Kim Nguu River system (Trinh *et al*., 2007). Water from the Nhue River has been used for agricultural and aqua cultural activities. The total basin of this river is more than 1,000 km^2 ha: 880 km^2 ha for Hanoi and 200 km^2 for Ha Nam (Trinh *et al*., 2007). The Nhue River is considered highly polluted, especially in the Thanh Tri District where the tributaries To Lich and Kim Nguu Rivers carry wastewater from Hanoi.

In the present study, we examined the chemical properties of water from the Nhue River focusing on heavy metal pollution and the suitability of water quality for irrigation water.

MATERIALS AND METHODS

Materials

Surface water samples were collected at 10 locations from upstream and downstream of the Nhue River (Fig. 1 and Table 4). At each location, water samples were taken four times in different seasons: December 2011

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and March 2012 (dry season), June 2012 and August 2012 (rainy season).

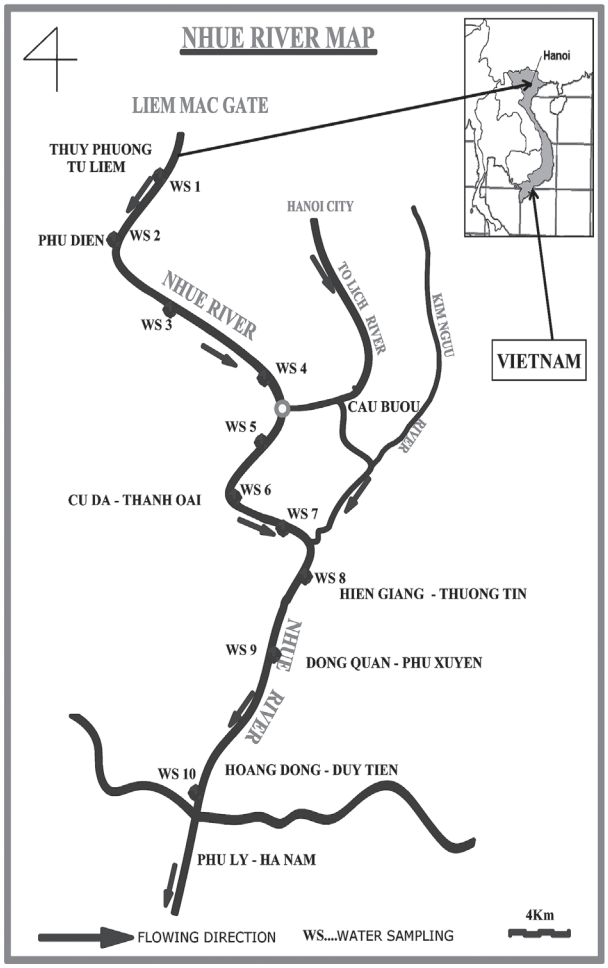

Fig. 1. Site sampling location.

Methodology

The pH of water was measured with pH meter (HM 30 G Horiba). Electric conductivity (EC) was determined using conductivity meter (CM 20S TOA). Dissolved oxygen (DO) was measured with the DO meter (Yellow Spring YS1 58). Chemical oxygen demand (COD) was determined by the permanganate ($KMnO_4$) method. For total suspended solids (TSS), original water samples were filtered using glass filtering paper, and then the solids remained was dried at 100°C and weighed. Total heavy metal concentrations were determined for non–filtered water samples, respectively. Heavy metals in the water samples were analyzed with atomic absorption spectrophotometer (AAS – Solar S2 Thermo electronic cooperation).

RESULTS AND DISCUSSIONS

Chemical Properties of Water

The mean value of chemical properties of water samples is summarized in Table 1. The pH ranged between 7.1 and 7.8 for dry season and 7.1 to 7.5 for rainy season. The pH of water samples from the To Lich and Kim Nguu Rivers is higher than that of other samples from the Nhue River (Nguyen *et al*., 2008). The EC ranged from 0.50 to 0.7 mS/cm for dry season and 0.45 to 0.6 for rainy season. The DO exhibited extremely low values of 2.0 to 4.4 mg/L for dry season and 2.1 to 5.0 mg/L for rainy season, which does not meet the Vietnamese requirement ($\geq$ 4 mg/L) for surface water, except for WS 1: 4.4 mg/L and 5.0 mg/L (for dry and rainy season) and WS 10: 4.2 mg/L and 4.7 mg/L (for dry and rainy seasons). The DO value of water from the To Lich and Kim Nguu Rivers was much lower than that of water from the Nhue River (Nguyen *et al*., 2008). The COD and TSS were in the widely range of 32 to 154 mg/L, 34–261 mg/L

Table 1. Chemical properties of water of the Nhue River

No	pH*	EC (mS/cm)	DO (mg/L)	COD (mg/L)	TSS (mg/L)	pH*	EC (mS/cm)	DO (mg/L)	COD (mg/L)	TSS (mg/L)
	Dry season					Rainy season				
WS1	7.1	0.50	4.4	34	34	7.1	0.45	5.0	24	24
WS2	7.5	0.56	3.0	86	53	7.3	0.50	3.8	76	43
WS3	7.8	0.58	2.8	102	83	7.5	0.53	3.2	92	73
WS4	7.7	0.65	2.5	110	194	7.3	0.60	3.0	100	174
WS5	7.8	0.76	1.3	143	261	7.5	0.70	2.3	133	230
WS6	7.7	0.70	2.0	106	114	7.4	0.65	2.3	96	94
WS7	7.5	0.65	2.3	75	89	7.4	0.60	2.5	65	79
WS8	7.4	0.65	1.8	154	164	7.3	0.60	2.1	134	144
WS9	7.5	0.60	3.1	96	119	7.3	0.55	3.8	76	109
WS10	7.3	0.50	4.2	32	52	7.1	0.50	4.7	25	42
MOSTE**	5.5–9		$\geq$ 4	<30	50	5.5–9		$\geq$ 4	<30	50

* *pH was measured on site*

** **MOSTE (08:2008 B1):** *applied to the surface water used for the purpose other than domestic water supply, including irrigation water*

Table 2. Correlation coefficient among the chemical properties of water

	pH	EC	DO	COD	TSS
pH	1				
EC	0.22	1			
DO	0.47	– 0.46	1		
COD	0.21	0.19	**– 0.92***	1	
TSS	0.39	0.01	0.25	0.35	1

** Significant at 1% level*

for dry season and 24 to 134 mg/L, 24–230 mg/L for rainy season, respectively, which exceeded the standard (MOSTE, 2008) by 1 to 5 times except for WS 1 and WS 10 at rainy season. The COD and TSS value of water samples from the To Lich and Kim Nguu Rivers were much higher than that of water samples from the Nhue River (Nguyen *et al*., 2008). Because of diluting by rainy water during the rainy season, the DO value of water sample at rainy season was higher than that of dry season; however the values of COD and TSS of water sample at rainy season were lower than that of dry season.

Table 2 shows the correlation coefficients among the chemical properties of the water samples. The correlation coefficient was significant between DO and COD, but was not for other combinations of the chemical properties.

Heavy Metal Pollution Assessment

Table 3 shows the mean value total heavy metal concentrations of the water samples during the dry and rainy seasons. The average total metal concentrations of the samples containing suspended solids was in the order of Zn > Pb > Cu > Ni > Cr > Cd. In general, the total heavy metal concentrations of water samples in dry season were much higher than that of rainy season.

The almost total heavy metal concentrations for Cd, Cr, Cu, Ni, Pb and Zn exceeded the permissible level of the surface water standard (MOSTE, 2008) for both dry and rainy seasons, except the total heavy metal concentrations of WS 1 and WS 10 (at the upstream and downstream of the Nhue River). However, total heavy metal concentration for Cr, Pb and Zn were well within the permissible level of WHO. The total heavy metal concentration of water sample in the rainy season was lower than that of in dry season.

To assess how the effluents from industrial plants located in the areas of the sampling sites affect water quality of the Nhue River, information on the plants in each area is presented in Table 4 along with the total heavy metal concentrations of the water samples. The extremely high Cd concentration (0.09 mg/L) was found in WS 2 for the Nhue River, which would be due to effluents from the painting and mechanical factory in Phu Dien area. The highest concentration of Cr (0.09 mg/L) at the Nhue River was found in WS 2, which would be attributed to effluents from the painting and mechanical factory in Phu Dien area. The high concentrations of Ni and Pb were found in WS 5, WS 6 and WS 7 (Ni = 0.25 mg/kg, Pb = 1.1 mg/L). These samples were taken at the sites where wastewater from the mechanical factory is flowing into. The Cu accumulated in sediment is derived mainly from textile and shoe industrial sectors (Marcussen *et al*., 2006). Hence the high Cu concentrations for WS 3 and WS 4 (1.0 mg/L) can be ascribed to wastewater from the Van Phuc textile in Ha Dong district. Brigden and Santillo (2006) indicated that Cd, Ni and Zn are used in battery manufacturing processes,

Table 3. Heavy metal concentrations of water of the Nhue River

No	Total heavy metal concentration Dry season (mg/L)						Total heavy metal concentration Rainy season (mg/L)					
	Cd	Cr	Cu	Ni	Pb	Zn	Cd	Cr	Cu	Ni	Pb	Zn
WS1	0.009	0.03	0.2	0.07	0.2	1.1	0.008	0.02	0.1	0.05	0.1	1.0
WS2	0.09	0.09	0.4	0.09	0.3	1.3	0.09	0.04	0.3	0.07	0.2	1.2
WS3	0.03	0.08	1.0	0.12	0.6	1.5	0.01	0.05	0.7	0.1	0.5	1.3
WS4	0.06	0.07	1.0	0.17	0.8	1.6	0.06	0.06	0.7	0.15	0.7	1.5
WS5	0.06	0.07	0.9	0.25	1.1	1.7	0.07	0.07	0.7	0.2	1.0	1.6
WS6	0.05	0.08	0.9	0.20	0.9	1.5	0.05	0.07	0.8	0.15	0.8	1.4
WS7	0.04	0.07	0.8	0.15	0.8	1.2	0.04	0.05	0.7	0.1	0.7	1.0
WS8	0.05	0.07	0.9	0.23	0.8	1.5	0.05	0.04	0.8	0.2	0.7	1.5
WS9	0.03	0.05	0.7	0.2	0.6	1.6	0.03	0.04	0.5	0.15	0.5	1.5
WS10	0.01	0.03	0.3	0.15	0.3	1.3	0.009	0.02	0.2	0.1	0.2	1.0
MOSTE**	0.01	0.04	0.5	0.1	0.5	1.5	0.01	0.04	0.5	0.1	0.5	1.5
WHO***	0.01	0.1	0.2	0.2	5	2	0.01	0.1	0.2	0.2	5	2

** pH was measured in a laboratory*

*** **MOSTE (08:2008 B1):** applied to the surface water used for the purpose other than domestic water supply, including irrigation water*

**** Irrigation water standard (WHO, 1989)*

Table 4. Information on the industrial plants in the areas of water sampling sites and the total heavy metal concentrations of water

No. of sampling site	Location	Type of industrial plants	Total heavy metal concentration of water (mg/L)
WS 1	Thuy Phuong	None	
WS 2	Phu Dien	Painting Mechanical	Cd (0.9) Cr (0.09)
WS 3	Van Phuc	Textile	Cu (1.0)
WS 4	Huu Hoa		
WS5	Ta Thanh Oai	Machine	Ni (0.25) Pb (1.1) Zn (1.7)
WS 6	Dai Ang		
WS 7	Cu Da		
WS 8	Hien Giang	None	
WS 9	Dong Quan	None	
WS 0	Hoang Dong	None	

and water and sediment in a drain are heavily contaminated with those heavy metals. The highest Zn concentrations for WS 5 (1.7 mg/L) can be ascribed to also effluents from the mechanical factory. The concentrations of Cd and Ni were rather low for water samples WS 8 – WS 10.

Suitability for Irrigation Water

Currently water from the Nhue River is being supplied to the agricultural land of various communes from Hanoi city to Ha Nam provinces.

The irrigation water standard for heavy metals (WHO, 1989) is shown in Table 3. The total heavy metal concentration in water was compared with the irrigation water standard. The total heavy metal concentrations in all sites exceeded the permissible level for Cd, Cu and Ni (except WS 1) and were within the permissible level for Cr, Pb and Zn. Particularly the total Ni concentration in the water samples WS 5 to WS 9 (for dry season) and WS 5 to WS 8 (for rainy season) higher than the permissible concentration (0.2 mg/L).

Excess of certain trace elements in irrigation water can retard the growth and metabolic activities of plants in agricultural land. The primary routes of exposure of humans to trace elements in soil are through food chain transfer and by direct ingestion of soil particles. Documented cases of chronic adverse health effects due to trace element exposure through food chain transfer or direct ingestion of soil are more numerous. Toxic elements which accumulate in the soil move into the edible parts of crops, posing considerable health risk to humans and animals (Pillay *et al*., 2003).

The fact that the irrigation water from the Nhue River is heavily polluted with heavy metals suggests that the irrigated agricultural land in suburban areas and the crops cultivated there are also polluted with heavy metals. Hence, further study is needed to assess the effects of heavy metals in irrigation water on the pollution of agricultural soil and metal accumulation in farm products.

CONCLUSIONS

Water from the Nhue River is heavily polluted with heavy metals such as Pb, Cu, Zn, Cr, Cd and Ni. The DO, COD, and TSS of the water as organic matter indexes and the concentrations of all heavy metals exceed the Vietnamese standard for surface water quality (MOSTE, 2008) in allmost investigated sites. The concentrations of some heavy metals such as Cu, Cd and Ni exceed the WHO permissible level for irrigation water. A wide variation in heavy metal concentration due to metal types is the result of wastewater discharged from different industrial sources.

To reduce the pollutants discharged from the industrial plants located along the rivers, countermeasures by the government and the technological improvement of wastewater treatment in manufacturing processes are needed. For further study, we need to assess the effects of heavy metals in irrigation water on the pollution of agricultural soil and metal accumulation in farm products.

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