VNU Journal of Science, Earth Sciences 26 (2010) 42-47

Characteristic of urban wastewater in Hanoi City – nutritive value and potential risk in using for agriculture

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Received 9 September 2010; received in revised form 11 October 2010

Abstract. Reusing domestic wastewater for irrigation is a common practice in peri-urban areas in Vietnam. This study investigates the characteristic of domestic wastewater in Hanoi City in terms of nutritive value and potential risk in using for agriculture. The wastewater samples were collected in four main drainage rivers of the City including Lu, Set, Kim Nguu, and To Lich River during March to May 2010. We found that the wastewater of Hanoi City is seriously polluted by organic matters. The nutrient parameters were really high and which is suitable for agricultural irrigation. The wastewater might supply enough nutrients for plant growing. However, municipal wastewater contains a variety of inorganic substances from domestic and industrial sources, including a number of potentially toxic elements such as 1.09-2.14 µg Cd L^{-1}, 0.16-0.33 mg Cu L^{-1}, 2.75-4.02 µg Pb L^{-1}, 0.20-0.34 mg Zn L^{-1} and 0.22-0.44 mg Mn L^{-1}. These were also a significant quantities of heavy metals being higher than natural river water, and possible threat to soil biota and hence on microbial and faunal activity, and then human health.

Keywords: heavy metals, irrigation, trace metals, treatment, wastewater.

1. Introduction

Wastewater is sewage, storm-water and water that has been used for various purposes around the community. Unless properly treated, wastewater can harm public health and the environment. Urban wastewater pollution sources are very variables, depending on the levels of development, population and the location of the urban area. Most communities generate wastewater from both residential and non-residential sources. Other categories of wastewater sources are generated with four sources (1) municipal wastewater; (2) industrial wastewaters, (3) agricultural wastewater and (4) storm-water runoff [1]. The municipal wastewater consists of a combination of domestic wastewater, originating in households, offices, and public restrooms, and lesser contributions from many commercial and small industrial sources [1, 2]. This source brings potentially nutrient parameters for agriculture [3, 4].

Reusing urban wastewater for agricultural production has been applied in many countries as well as continents [4,5]. In some sub-urban

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areas the use of wastewater and sewage sludge for irrigation and fertilizers is a common practice and popular [1-6]. Wastewater is often the only source of water for irrigation. Even in areas where wastewater source is not the sole water source for agricultural irrigation, farmers still prefer using sewage for irrigation, by reason of its nutritive value, which reduces expenditure on chemical fertilizer [6].

However, potential toxic substances are usually found in wastewater, which may limit the long-term use of wastewater for agricultural purpose [4,6]. Wastewater is harmful not only to fish breeding and agricultural products, but also to public health in surrounding areas [6]. Of the pollutants, heavy metals can endanger public health by being incorporated into food chain [7]. Heavy metals are not biodegradable and tend to accumulate in the sediments of waterways in association with organic and inorganic matter in the sediments [8]. In the present study, we examined the nutritive value and potential risk of using wastewater of Hanoi City for agricultural cultivation.

2. Materials and methods

2.1. Study site

The study was carried out in Hanoi, the capital city of Vietnam. Hanoi City comprises ten inner city districts and 19 outer city districts of a total area of 332 490 ha with the population of 6.3 million people. In Hanoi, the urbanization process is presently going on very rapidly. The inner City area is of 198 km^2, but the population is concentrated with 2.4 million people [9]. Especially in this area there are still many old factories, enterprises, causing serious environmental pollution that had been warned by Hanoi environmental protection agency. However, sewage of Hanoi is a main water source supplying irrigation water to the peri-urban areas of Hanoi such as Thanh Tri, Thuong Tin districts, and some other areas belonging to Ha Nam province.

This study was mainly concentrated on the characteristic of wastewater in the inner Hanoi city. Wastewater samples were taken from the water drainage rivers system of Hanoi: To Lich river, Lu river, Set river and Kim Nguu river.

2.2. Study site

The samples are taken along the water drainage rivers of Hanoi. They are briefly described in Table 1. Waste water samples were sampled every two week during March-May 2010 for each site. After sampling the wastewater samples were stored, and pretreated for analyzing.

Table 1. Brief description of wastewater samples

River	Location of wastewater sample	Possition	
		Latitude, N	Longitude, E
Lu	Dinh Cong commune	20°58'34.63"	105°49'58.30"
Set	Set bridge	20°58'54.80"	105°50'44.77"
Kim Nguu	Mai Dong bridge	20°59'46.37"	105°51'44.29"
	Van Dien commune	20°57'14.88"	105°50'28.27"
To Lich	Moi bridge	21° 0'4.64"	105°49'5.94"
	Dau bridge	20°58'11.36"	105°49'28.78"

2.3. Method of analyzes

Wastewater samples were analyzed for pH, chemical oxygen demand (COD), N, P, K, Cd, Cu, Pb and Zn. pH was measured by using pH meter immediately after sampling, chemical oxygen demand (COD) was used $K_2Cr_2O_7$ method. Metal concentrations were analyzed for P, K, Cd, Cu, Pb and Zn after digestion with boiling concentrated HNO_3 [10]. Total N (N_{total}) was quantified as the sum of four N forms: nitrate-N (NO_3^--N), nitrite-N (NO_2^--N), ammonium-N (NH_3-N) and organic-N (N_{org}). NO_2^--N and NO_3^--N were determined colorimetrically, NH_3-N was determined by a titration method after distillation, and N_{org} was determined by macro-Kjeldahl methods [10].

3. Results and discussion

3.1. River - drainage system in Hanoi City

The four rivers are playing a very important role in water drainage in Hanoi inner. The lengths and basin areas of these rivers are shown in the following table (Table 2).

Table 2. Characteristics of water drainage rivers of Hanoi

No	Name of river	Basin area (ha)	Length (km)	Wide (m)	Begin of river	End of river
1	Lu	560	5.8	20-30	Trinh Hoai Duc	Dinh Cong commune (To Lich river)
2	Set	580	6.7	10-30	Tran Khat Tran	Giap Nhi commune (To Lich river)
3	Kim Ngu	1400	12.2	25-30	Lo Duc	Son bridge (To Lich river)
4	To Lich	2000	14.8	30-40	Phan Dinh Phung	To bridge
	Total	4540	39.5	10-40		

Lu river:

Lu river is 5.8 km long, 20-30 m wide, 4m deep, derived from Trinh Hoai Duc sluice, flowing through Dong Da lake, Trung Tu lake, Linh Dam lake and to To Lich river in Dinh Cong commune. Lu river basin area is 560 ha with a population of 200 thousand people. The volume of sewage discharged into the river ranges from 50,000 – 55,000 m^3 day^{-1}.

Set river:

Set river is derived from Tran Khat Chan sluice, flowing through Hanoi Technical University, Dai La bridge, and in to Kim Nguu river in Giap Nhi commune. The river is 6.7 km long, 10-30 m wide in average, 3-4 m deep. The basin area of Set river is 580 ha with a population of 250 thousand people. The totals of wastewater discharged in to the river ranges from 65,000-70,000 m^3 day^{-1}.

Kim Nguu river:

The river is derived from Lo Duc sluice, 12.2 km long, receives all sewage from the basin of Lo Duc, Quynh Loi, Mai Huong, Vinh Tuy... with a total basin area of more than 1,400 ha and a population of more than 500 thousand people. Kim Nguu river merges into To Lich river at Son bridge closer to Thanh Liet dam. Kim Nguu river from the inner city is about 90,000 – 105,000 m^3 day^{-1}.

To Lich river:

The To Lich river begins at the West Lake and flows into the Nhue River. To Lich river is the main drainage river of Hanoi's inner city. Sewage from the 3 rivers above is discharged into To Lich river. The river begins from Phan Dinh Phung sluice, through channels Thuy Khue, Buoi, Cau Giay, Cau Moi to Thanh Liet dam, discharged into Nhue river at To bridge or

flowing to Hoa Binh dam in the south of Hanoi. The river is 14.8 km long, 30 – 40 m wide, 3-4 m deep. The main basin area, excluding the basin area of the 3 rivers above, is 2,000 ha, the sewage flow is of 110,000- 125,000 m^3 day^{-1}, with a population of more than 560 thousand people.

3.2. Wastewater characteristics

The results of wastewater analyzes are presented in Table 3.

Table 3. Characteristic of wastewater in drainage river system of Hanoi City

Nº	Parameters	Unit	Lu river	Set river	Kim Nguu river		To Lich river	
			Dinh Cong commune	Set bridge	Mai Dong bridge	Van Dien commune	Moi bridge	Dau bridge
1	pH		7.43±0.22	7.49±0.25	7.56±0.29	7.53±0.25	7.57±0.31	7.44±0.31
2	SS	mg L^{-1}	117±24	75±27	57±14	72±18	112±20	151±30
3	COD	mg O_2 L^{-1}	123±41	125±34	118±17	67±7	101±40	119±51
4	N_{total}	mg N L^{-1}	12.2±4.7	12.7±4.8	12.8±5.0	8.0±3.4	13.1±4.4	13.1±3.4
5	P_{total}	mg P L^{-1}	3.8±1.2	3.7±1.1	3.4±1.2	3.3±0.9	3.6±1.4	3.7±1.4
6	K_{total}	mg K L^{-1}	11.4±3.4	10.3±1.9	11.8±2.2	9.6±2.7	11.7±1.8	13.2±2.1
7	Cd	µg Cd L^{-1}	1.19±0.89	1.11±0.89	1.32±0.94	2.14±1.88	1.59±1.03	1.09±0.98
8	Pb	µg Pb L^{-1}	3.92±1.44	3.53±1.46	3.54±1.39	4.02±1.55	4.45±1.94	2.75±1.05
9	Cu	mg Cu L^{-1}	0.25±0.09	0.22±0.10	0.27±0.09	0.33±0.08	0.32±0.15	0.16±0.07
10	Zn	mg Zn L^{-1}	0.25±0.12	0.24±0.12	0.30±0.17	0.32±0.17	0.34±0.17	0.20±0.11
11	Mn	mg Mn L^{-1}	0.32±0.09	0.29±0.10	0.35±0.12	0.42±0.15	0.44±0.17	0.22±0.06

pH, SS and COD

The water quality determined is summarized in Table 3. The pH ranged between 7.20 and 7.87. The chemical oxygen demand (COD) and suspended solid (SS) in water were high, and much higher than the maximum allowable concentration of National technical regulation on surface water quality, QCVN 08:2008/BTNMT column B1 [11].

Nutrient parameters: N, P, K

The result obtained from analyzes of nutrition criteria in water at the studied area shows that total nitrogen (N_{total}) ranged from 4.6 to 17.8 mg L^{-1}, the average value was 11.9 mg L^{-1}. Potassium (K) content in water was also relatively high, ranging from 4.1 – 17.3 mg L^{-1}, the average value was 11.3 mg L^{-1}. Total phosphorus content (P_{total}) ranged from 1.0 – 6.7 mg L^{-1}, the average value was 3.6 mg L^{-1}. Considering the aspects of nutrition and availability of using sewage as irrigation water, wastewater of Hanoi contains high content of nutrients suitable for reuse of agricultural irrigation. Normally, nutrients parameters of urban wastewater are higher than those in natural water. A comparison of nutrient parameter in the river wastewater system to Red river water found that the N_{total}, P_{total} and K_{total} in urban wastewater was 3.5, 7.1 and 10.9 times respectively higher than the Red River water [5].

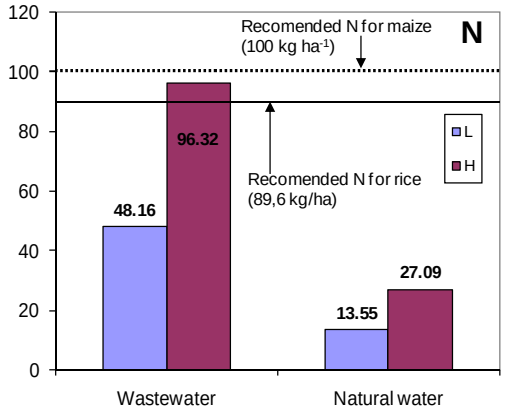
Heavy metals

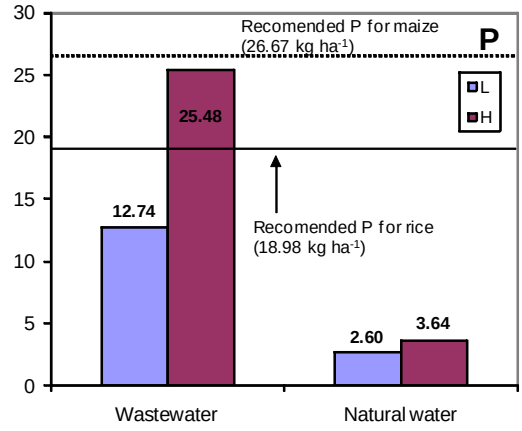
The concentration of heavy metals including cadmium (Cd), lead (Pb), and copper (Cu) in urban wastewater is presented in Table 3. The mean value heavy metal contents ranged

from 1.09 – 2.14 µg L^{-1} for Cd, 2.75-4.02 µg L^{-1} for Pb, and 0.16-0.33, 0.20-0.34, 0.22-0.44 mg L^{-1} for Cu, Zn, Mn respectively.

Valuable of nutrients and potential risk

The results in Table 2 and Table 3 showed that in average, every 1 m^3 of wastewater contains 13.76 g for N; 3.64 g for P and 11.58 g for K, this is a very good nutrient supply source. Based on appropriate nutrition demand of rice and maize, as well as the volume of irrigation water necessary for 1 crop, the capacity of supplying nutrients of sewage is shown in the following Fig 1.





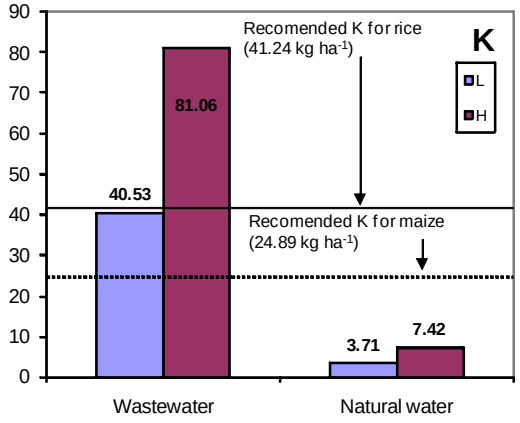


Fig 1. A comparison of capacity supplying nutrients for N, P, K by using wastewater and river water for irrigation (kg ha^{-1}). Two horizontal lines show the nutrition demand for N, P, K of rice and maize. H and L indicated the demand supplying of water being high level (7000 m^3 ha^{-1}) and low level (3500 m^3 ha^{-1}), respectively.

Fig 1. showed the capacity of supplying nutrients through wastewater for agriculture is very high. In many case, the wastewater supplies enough nutrient for plant growing. However, municipal wastewater contains a variety of inorganic substances from domestic and industrial sources, including a number of potentially toxic elements such as arsenic (As), Cd, chromium (Cr), Cu, mercury (Hg), Pb, Zn, *etc* [12]. The present study found that a cubic meter of wastewater contained about 1.09-2.14 mg Cd; 0.16-0.33 g Cu; 2.75-4.02 mg Pb, 0.20-0.34 g Zn and 0.22-0.44 g Mn. These were also significant quantities of heavy metals, and possible threats to human health [7]. Even if the toxic materials in wastewater are not present in concentrations likely to affect humans or to limit their agricultural use, they might be higher than concentrations in natural river water, which would lead to contamination of agricultural soils in the long-term [14]. Wang (2005) studied the impact of sewage irrigation

on trace metal contamination in Beijing and stressed that metals were enriched in soil due to sewage irrigation. This was also the conclusion in earlier publications regarding the potential risk of sewage irrigation on soils, crop production and human health [5-8, 12-14].

4. Conclusion

Wastewater characteristic of Hanoi city was polluted with organic matter. The nutrient parameter was really high and suitable for agricultural irrigation. The wastewater might supply enough nutrients for plant growing. However, municipal wastewater contains a variety of inorganic substances from domestic and industrial sources, including a number of potentially toxic elements such as 1.09 - 2.14 µg Cd L^{-1}, 0.16 - 0.33 mg Cu L^{-1}, 2.75 - 4.02 µg Pb L^{-1}, 0.20 - 0.34 mg Zn L^{-1} and 0.22 - 0.44 mg Mn L^{-1}. These were a significant quantity of heavy metals, and possible threats to soil biota, and then human health.

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