SURVEY OF SOURCES, ROUTES AND FATE OF PATHOGENS IN THE WATER ENVIRONMENT IN MONSOON ASIA

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ABSTRACT

Two lagoons in Monsoon Asia were selected for the targets of this research to compare the effect of sewerage system on wastewater quality. As results, the concentration in wastewater of one type was higher than that of the other. It was estimated that the concentration of water quality became higher after the spread of flushing toilet. Pathogens, such as E. coli, Norovirus and Giardia, were detected in both lagoons and treated effectively by them. Although the removal ratio was high, the value was not steady during the investigation. On the other hand, considering the effets of intensive rainfall, the water quantity and water quality were investigated in the river of urban area. The pathogen loads of water qurity in the river was estimated by the results. The maintnance of lagoons and toilets (infiltration toilet and septic tank) would be important in the drainage area of logoons. After that, the lagoons would have good possibility for the preservaiotn of water environment.

KEYWORDS

Lagoon; pathogen; protozoa; urban areas; virus; river

INTRODUCTION

Rapid growth of population, urbanization, delayed sewerage system construction and intensive rainfall in Monsoon Asia have polluted urban water environments with pathogens originating from human feces. After pathogens are discharged by human beings, they travel various routes such as flowing through diches and streams, being transported in sewer pipes to be treated in treatment plants, or overflowing sewer pipes during rainfall, until they fainally reach the water environment.

To evaluate pathogen risks for people living in Monsoon Asia, the sources, routes and fate of pathgens in the water environment must be investigated. This research surveied the sources of pathogens, the temporal and spatial fluctuations of pathogen loads on the water environment, pathogen removal effects of sewage treatment plants, and the fate of pathogens in the water environment.

METHODS

Fate of pathogens in sewage treatment plants in Monsoon Asia

Lagoons perform most sewage treatment in Monsoon Asia, and the characteristics of the removal or inactivation of pathogens by these lagoons must be evaluated in terms of the effects of temperature, sunlight intensity and amount of rainfall. Lagoons are sometimes backed up by wetlands, and this supplemental process must also be performed efficiently.

The first aim of this research was to develop indicator microorganisms representative of three pathogen groups: bacteria, protozoa and viruses. Then these indicators would be applied to evaluate the effects ot the type of lagoon, the wetland and climate conditions on the fate of pathogens.

In the first year of the research, the surveys were conducted using an experimental lagoon installed in a sewage treatment plant in Okinawa, Japan. In the second year, the surveys of lagoons in Thailand, the Mekong watershed, were conducted. Generaly, it is considered that the wastewater in Thailand is greywater. In comparison with an usual lagoon, a spesific lagoon which has own sewerage system with flushing toilet was investigated.

Discharge of pathogens from urban areas

Although many studies of various urban sources of water pollution have been carried out, analyses of the effect of rainfall on pollution and of the pathogen loads on the water environment have not been sufficiently conducted, because complete surveys have not been performed. However, such studies are needed to take measures to fight pollution in areas where feces are not sanitary treated or areas that are served by combined sewers.

The second aim of this research was to clarify the fate of pathogens in the water environment by investigating the distribution, discharge routs and loads of pathogens in the urban water environment. In the third year, the surveys of river in urban areas were conducted. And the pathogen loads from infiltration toilets and septic tanks were estimated in the drainage area of lagoons. After that, the role of lagoons for water environment was estimated.

RESULTS AND DISCUSSION

Surveys of lagoons in Thailand

It is estimated that the characteristics of wastewater are significantly different according to the consumption of water and the type of toilet. Two lagoons in Khon Kaen and Asian Institute of Technology (AIT) were selected for the targets of this research to compare the effect of sewerage system. Khon Kaen City has a combined sewer system, and its sewer is collected by the water course along the river and carried to the lagoon. Each house has an infiltration tank or a septic tank in Khon Kaen. On the other hand, AIT has its own sewarage system with flushing toilet.

This research was conducted under the co-operation of Khon Kaen University and AIT. Surveys were carrried out at both Khon Kaen Municipal WWTP (Wastewater Treatment Plant) and AIT Campus WWTP. Figure 1 and Figure 2 show their lagoons and sampling stations. Khon Kaen has two lines of lagoons, and each line has three ponds (aerobic, anaerobic and settling). Total volume of three ponds is about 46,000m^3 and the average water depth is 2m. AIT has two lines of lagoons and one line of wetland. Each line of lagoons has two ponds (aerobic and settling). The volume of two lagoons is 2,125m^3 and 3,360m^3, and the water depth is 1.7m and 0.7m respectively.

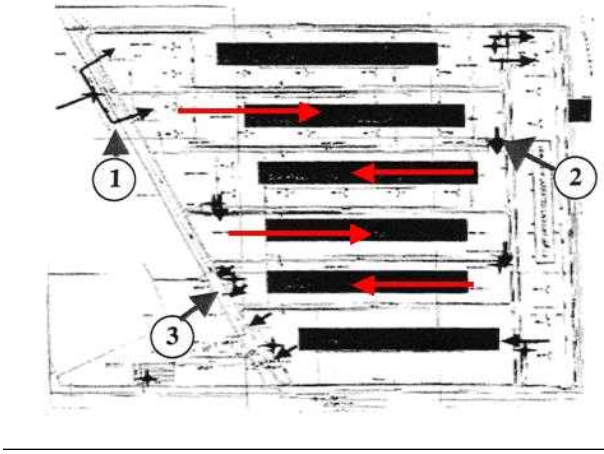

Figure 1. Khon Kaen Municipal WWTP (1: influent, 2: aerated, 3: effluent)

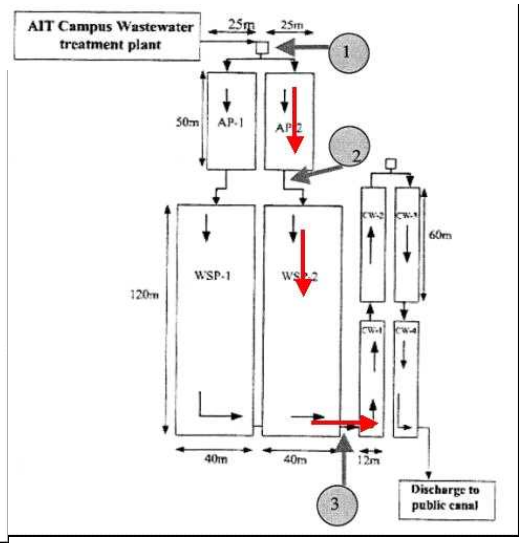

Figure 2. AIT Campus WWTP (1: influent, 2: effluent 1, 3: effluent 2)

Regular sampling was conducted once or twice a month for estimating the seasonal fluctuation of water quality. Generally, in Monsoon Asia there are wet season and dry season. It was estimated that an amount of rainfall has an effect on the volume and quality of influent wastewater considerably. And whole day sampling was also conducted twice a year during wet season and dry season. It was considered that a sunlight intensity had an effect on the pH value and the dissolved oxygen (DO) during one day. Table 1 shows the water quality parameters, which are measured at both WWTP.

Table 1. Water Quality Parameters

Climate	Temperature	Chemical (cont.)	Chemical Oxygen Demand (COD)
	Sunlight		Total Suspended Solids (SS)
	Precipitation		Total Nitrogen (T-N)*
Physical	Water Temperature		Total Phosphours (T-P)*
	Water flow to pond		Chlorophyll a
Chemical	pH	Biological	Total Coliform and E. coli
	Dissolved Oxygen (DO)		Giardia and Cryptosporidium
	Biochemical Oxygen Demand (BOD)		Norovirus and Enterovirus

* at only Khon Kaen Municipal WWTP

Organic materials

From the results of surveys of lagoons from July 2004 to March 2005, the average concentration of influent was 21mg/L (BOD) and 72mg/L (COD) at Khon Kaen Municipal WWTP and the effluent concentration was sometimes larger than that of influent. In contrast, that of AIT Campus WWTP was 63mg/L (BOD) and 169mg/L (COD) and the average removal ratio of BOD and COD was 65% and 59% in that order. It was considered that the lagoon, which has its own sewerage system with flushing toilet, has a function to reduce the organic materials in wastewater.

Pathogens

The results are indicated in Table 2. The pathogens concentration in influent of Khon Kaen Municipal WWTP was not larger than those of AIT Campus WWTP, because the type of sewerage system is different. While Cryptosporidium was not detected in Khon Kaen, the maximum data of Norovirus in influent was 2 orders larger than that of Okinawa.

On the other hand, maximum data of Giardia and Norovirus G1 in influent of AIT were 1.8E+04 cysts/L and 1.8E+07 copies/L respectively. Those data was 2 or 3 orders larger than those of Okinawa, but the data of Total coliform was same level. In comparison with the results of Cryptosporidium in influent of Japan, the rate of detection was relatively large and concentration was same level.

The concentration of pathogens in effluent, which is considered to have a great influence on water environment, was observed low level at both lagoons. The average removal ratio of pathogens was more than one to three in logarithm. And the removal ratio of Total coliform and Giardia were larger than those of Okinawa. The reasons were considered that the lagoons were arranged multiple and the retention period was different between two cities. While the removal ratio of Norovirus was not steady during the investigation, a significance difference was not observed between the removal ratio and the water quality parameters, such as dissolved oxygen.

Table 2. Concentration Range and Removal Ratio of Pathogens

		Total coliform (cfu or MPN/ml)	Norovirus G1 (copies/L)	Norovirus G2 (copies/L)	Giardia (cysts/L)	Cryptosporidium (oocysts/L)
	Sampling Time	June 2004〜Feb, March 2005	June 2004 〜 March 2005		June 2004 〜 March 2005	
Khon Kaen Municipal WWTP	influent	4.4E+2〜2.3E+5	8.6E+3〜9.7E+5	4.1E+2〜1.6E+5	ND〜1.5E+2 〔13/16〕	ND 〔0/16〕
	aerated	4.0E+1〜3.0E+4	ND〜1.7E+4	ND〜1.7E+4	ND〜2.2E+1 〔4/16〕	ND 〔0/16〕
	effluent	3.8E+1〜2.2E+4	ND〜6.9E+3	ND〜1.0E+4	ND〜1.0E+0 〔1/16〕	ND 〔0/16〕
	(range removal %)	0〜99.6	82.4〜100	0〜100	99.3〜100	—
	(ave. removal %)	83.2	95.2	89.0	99.9	—
AIT Campus WWTP	influent	2.1E+4〜9.0E+6	2.7E+4〜1.8E+7	1.1E+4〜2.0E+6	2.6E+2〜1.8E+4 〔21/21〕	ND〜1.6E+1 〔14/21〕
	effluent 1	4.6E+3〜1.6E+6	6.2E+4〜2.2E+6	1.3E+4〜1.3E+6	1.1E+1〜4.1E+2 〔13/13〕	ND〜2.0E+0 〔2/13〕
	effluent 2	7.0E+1〜5.0E+3	3.6E+1〜4.2E+5	ND〜6.0E+4	ND〜5.6E+1 〔20/21〕	ND 〔0/21〕
	(range removal %)	98.1〜99.9	0〜99.9	56.2〜100	94.6〜100	100
	(ave. removal %)	99.6	74.1	92.1	99.4	100

* Giardia and Cryptosporidium: [detaction numbers / sample numbers]

Surveys of river in urban areas

It is estimated that a large amount of rain water discharge into river after intensive rainfall. To estimate the pathogen load on water environment, basic survey was conducted at river in Khon Kaen. Figure 3 shows the survey point at Rong Muang Canal, where is just the upper stream of fainal pump station. At first, the survey point was determined at the river in urban areas. The point would be the last point where overflow flow from the water course along the river was almost finished. And the cross section size of the canal at sampling point was provided from Khon Kaen Municipal Office (Figure 4).

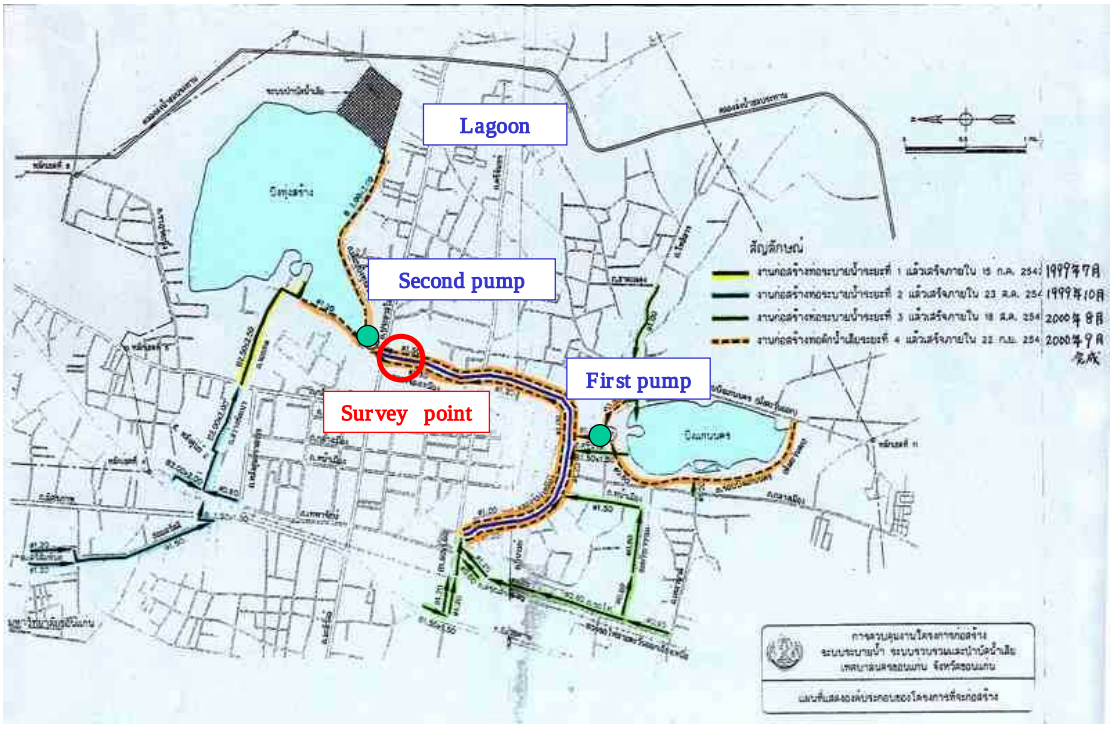

Figure 3. Location of Survey Point in Khon Kaen

Next, the water depth (H) and water quantity (Q) was measured at several times. And the H-Q curve was culculated. In this research, a velocity of flowing water was measured by using a buoy. In shiny day, water sampling was conducted every 2 hours for whole day from around 8 to 16 o'clock. In rainy day, water sampling was conducted every 10 minute until the water depth become usual level or before dark. Water quality parameters were BOD, COD, pH, Water Temperature, DO, SS and pathogens.

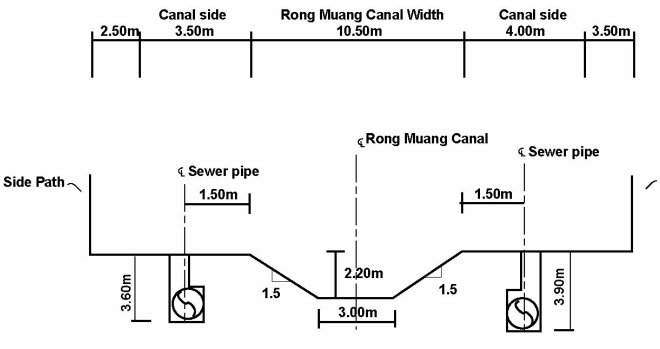

Figure 4. Cross Section at Survey Point

Water quality in river

The results are indicated in Table 3. Sampling was conducted 4 times in rainy day and 3 times in sunny day between August and September in 2005. And the total samples for analysis became 22 in rainy day and 15 in sunny day. In rainy day, it is difficult to forecast the weather and catch the peak of water quantity and water quality. Because the river basin is too small for an intensive rainfall, the rain flushes into the river rapidly.

The detection ratio and concentration of Norovirus decreased in rainy day, because the water quality would be diluted by the rain water. And the maximum data of E. coli in rainy day was also lower than that of sunny day. But the maximum data of Giardia in rainy day was about 10 times larger than that of sunny day. These results would need to be clarified by further investigation.

Table 3. Water Quality in River

ave. water quantity range (m3/s)		E. coli (MPN/100 ml)	Cryptosporidium (oocysts/L)	Giardia (cysts/L)	Norovirus G1 (copies/L)	Norovirus G2 (copies/L)
rainy day	concentration range	5.1E+3〜3.5E+4	ND	5.0E+0〜2.0E+2	1.60E+02	5.30E+02
1.6〜12.6	detection ／ sample number	10/10	0/22	10/22	1/22	1/22
sunny day	concentration range	1.2E+3〜9.2E+5	ND	2.0E+0〜2.6E+1	4.6E+2〜9.3E+2	1.3E+2〜1.1E+4
0.32〜1.56	detection ／ sample number	10/10	0/15	11/15	2/15	15/15

Pathogen loads from urban areas

In sunny day, the pathogen loads from urban area was observed. It was estimated that the loads originated from infiltration toilets and septic tanks. Especially in the drainage area of lagoons, the maintenance of toilets was very important to keep an effect of lagoon. Because the water is utilized repeatedly in watershed, lagoon would have an effect on the control infectious diseases. There are several fisheries in downstream of urban areas. Sometimes infectious diseases are catching by the foods which are polluted. The lagoons would have good possibility for the preservation of water environment.

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