FATE OF SANITARY INDICATORS IN TREATED WASTEWATER

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ABSTRACT

Treated wastewater quality standards need to be reviewed to improve the safety of water systems. However, much remains to be clarified concerning the fate of sanitary indicators in natural water. This research examines this topic.

For clarifying the fate of bacteria as indicators of sanitation, we conducted experiments using an experimental channel made of stainless steel. The parameters of the channel were changed for each experiment, namely the bed of the channel, temperature, flow rate, chlorine reduction, and inclination. The floor of the channel was stainless steel, gravel, or gravel with biofilm attached by secondary effluent run through the channel for about a month. We measured E. coli, coliform bacteria by desoxycolate and Chromocult, standard plate count, and general water quality indicators at the beginning and end of each experiment.

The results showed that the removal ratio of E. coli was almost 100% in all cases, though the removal ratios of other indicators were affected by temperature, chlorine reduction, and so on.

KEYWORDS

Coliform Bacteria, E. Coli, channel, disinfection

INTRODUCTION

Sewerage services have improved public health and preserved water qualities in public water bodies. The percentage of sewered population has reached 65.2% in Japan (Ministry of Land, Infrastructure, and Transportation (MLIT), 2003), and some sewage treatment plants are now located upstream of intake facilities. The importance of the sewage system is growing as its diffusion increases, making it necessary to consider space for siting, water recycling or reuse, and so on. Water quality must be kept safe and sanitary indicators monitored. However, the fate of coliform group, which is used as a sanitary indicator for treated wastewater in Japan as shown in Table 1, in natural water is not well understood. For example, it is well known that coliform group often increases after disinfection (e.g. T. Sumitomo, et al., 1993), so coliform group may not be suitable as a sanitary indicator. Indeed, for drinking water, the sanitary indicator has been changed from coliform group to E. coli.

To provide a reference sanitary indicator for treated wastewater, we surveyed in our laboratory the fates of some sanitary indicating bacteria in differently disinfected treated wastewaters, and in different water bodies receiving treated water flows. This report presents the results of some investigations we conducted using the experimental channel to clarify the

fate of sanitary indicators in natural water.

METHODS

This investigation focused on whether sanitary indicating bacteria in disinfected treated wastewater increase or decrease in natural water, because it was reported that indicating bacteria which decreased by chlorine disinfection tended to increase again from 100 to 200 hours later in cases of lower concentration chlorine disinfection (T. Hatatsu, et al., 1999). On the other hand, it was reported that indicating bacteria in not disinfected treated wastewater decreased after passing through an experimental channel (T. Hatatsu, et al., 2001). We therefore measured some indicating bacteria in disinfected wastewater after passing through the experimental channel.

Figures 1 and 2 show the experimental channel. Numbers in squares in Fig. 1 show the points where depths were measured. The experimental channel consists of a chlorine mixing tank, chlorine reduction tank, recycling tank, feeding pumps, and channel. The channel is

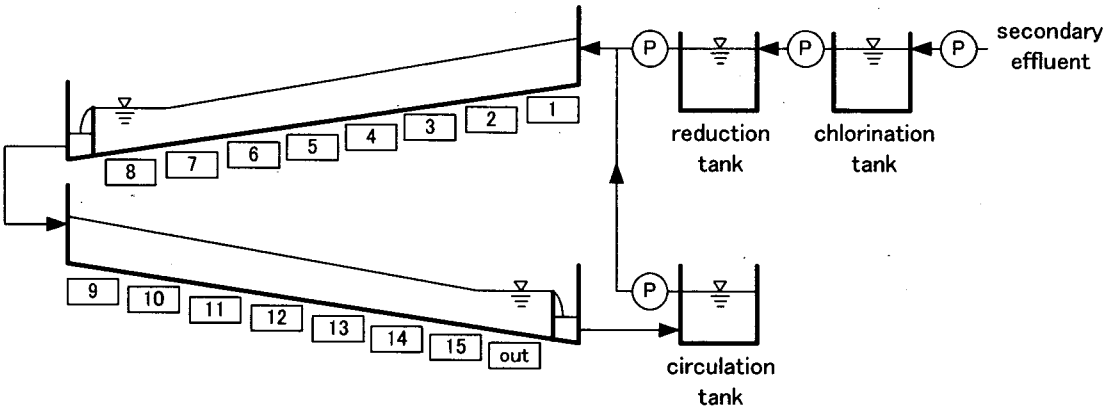

Fig. 1 The experimental channel

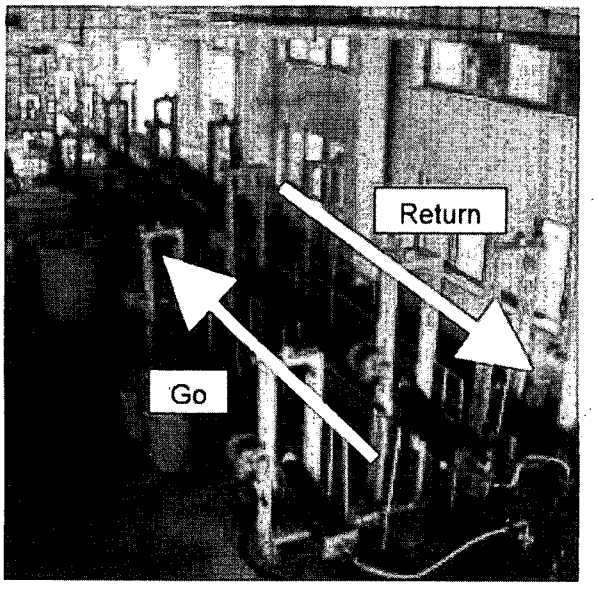

Fig. 2 The experimental channel

made of SUS, and is connected in series with two channels of 0.2 m wide and 30 m long (total length 60 m). Sample water can be passed through the channel either once, or cyclically by using a circulating pump. The inclination of the channel can be set freely.

The sample water was chlorine disinfected treated actual wastewater, which was taken from the pilot plant (10 m3 volume) of a conventional activated sludge process, or that reduced by sodium thiosulfate. Chlorine dosage was 0.5 mg/L and contact time was 15 min.

The indicating bacteria measured were coliform bacteria, E. coli, and standard plate count. E. coli was measured by Chromocult Coliform Agar which could distinguish E. coli by color, reflecting the activity of β-galactosidase and β-glucuronidase. Coliform bacteria were measured by desoxycholate agar and Chromocult Coliform Agar. Table 1 shows the indicating bacteria in Japan. Water temperature, pH, DO, COD, SS, nitrogen, and phosphorus were measured. Samples were taken from "1" in Fig. 1 at the beginning of each experiment and from 120 to 150 hours later, because it was shown that decreased coliform bacteria increased about 100 hours after chlorine disinfection (T. Hatatsu, et al., 2001).

Table 1 Sanitary indicators for water in Japan

Drinking water

indicator	unit	standards
standard plate count	[CFU/mL]	100
E. coli	[MPN/100mL]	N. D.

Bathing water

indicator		classification	unit	standards
Fecal coliform	good	water quality AA	[CFU/100mL]	N. D.
		water quality A	[CFU/100mL]	100
	fair	watar quality B	[CFU/100mL]	400
		water quality C	[CFU/100mL]	1000

Technical standards for treated wastewater

indicator	unit	standard
coliform bacteria	[CFU/mL]	3000

The conditions of the experimental channel are shown in Table 2. The channel bed was made of SUS, gravel, or gravel with biofilm. In the case of SUS, the experimental channel was cleaned using tap water before each experiment. In the case of gravel, the experimental channel and gravel were cleaned using tap water and the biofilm attached to gravel was removed before each experiment. In the case of gravel with biofilm, after cleaning the experimental channel and gravel, not disinfected treated wastewater of 15 L/min was passed through the channel one way for about one month, and biofilm was attached.

RESULTS

Table 2 shows the results. SS decreased in every case. It had been assumed that SS would be more in RUN 6 and 7 because it had turbulent flow and SS was raised, but SS decreased to the same level. Decreased SS seemed to lower during the period of the experiment from 120 to 150 hours. Exceptionally, SS did not decrease in the case of gravel bed with biofilm. The reason for this is thought to be that biofilm peeled off from the gravel with SS during sampling.

Table 2 The conditions of the experimental channel and the results of the experiment

			RUN 1		RUN 2		RUN 3		RUN 4		RUN 5		RUN 6		RUN 7		RUN 8	
			before	after	before	after	before	after	before	after	before	after	before	after	before	after	before	after
Conditions of experiment	channel bed				SUS								gravel				biofilm	
	reduction of chlorine		×		×		○		×		○		×		×		×	
	flow rate	[L/min]	15		15		15		15		15		100		100		15	
	inclination	[‰]	2.33		2.33		2.33		2.33		2.33		2.33		6.67		2.33	
Water qualities	water temperature	[°C]	10.3	8.4	25.4	23.5	21.8	21.4	13.8	9.9	24.9	23.9	12.7	11.5	13.2	13.3	17.4	22.7
	pH		6.8	7.8	6.4	7.5	7.1	6.9	7.6	7.1	6.5	6.0	6.5	7.5	6.5	7.6	6.2	5.4
	DO	[mg/L]	5.3	10.6	6.2	8.1	8.3	4.7	8.8	11.2	2.7	4.2	7.6	8.0	7.7	6.6	5.0	4.4
	free chlorine	[mg/L]	0.11	0.06	0.08	0.07	0.07	0.04	0.15	0.09	0.00	0.05	0.10	0.04	0.11	0.09	0.08	0.08
	total chlorine	[mg/L]	0.14	0.08	0.10	0.07	0.10	0.09	0.23	0.11	0.21	0.10	0.14	0.11	0.12	0.11	0.14	0.12
	COD_{Cr}	[mg/L]	52	54	28	8	59	21	40	54	37	14	51	17	20	31	26	21
	SS	[mg/L]	18.5	0.3	8.8	1.1	7.6	1.4	2.6	1.7	5.4	1.2	11.8	0.6	6.6	2.4	8.0	7.0
	T-N	[mg/L]	15.0	12.7	18.1	19.2	18.0	19.0	13.5	21.8	22.0	25.4	15.2	17.0	14.8	15.2	23.9	38.3
	NH_4-N	[mg/L]	1.8	0.1	0.2	0.0	0.1	0.1	1.0	0.1	0.2	0.1	0.3	0.1	0.1	0.1	0.1	0.6
	NO_2-N	[mg/L]	8.6	4.4	0.1	0.0	0.0	0.1	5.6	4.8	0.1	0.2	3.9	1.4	11.3	0.0	0.2	0.1
	NO_3-N	[mg/L]	1.7	5.9	22.9	18.9	12.6	17.2	3.7	12.3	16.5	16.4	7.1	14.5	2.0	13.7	20.9	33.4
	NO_X-N	[mg/L]	10.3	10.2	23.0	18.9	12.6	17.2	9.3	17.1	16.6	16.6	10.9	15.9	13.2	13.7	21.1	33.5
	T-P	[mg/L]	1.68	1.38	1.82	1.75	1.91	2.02	1.61	1.80	1.97	1.25	1.69	1.50	1.55	1.39	2.13	3.28
	PO_4-P	[mg/L]	1.23	1.25	1.75	1.71	1.70	1.76	1.42	1.67	1.68	1.72	1.36	1.50	1.39	1.47	1.60	2.85
Sanitary indicators	E. coli	[CFU/mL]	138	1	97	0	41	1	28	0	66	1	55	2	83	2	32	1
	coliform bacteria (chromo)	[CFU/mL]	2,125	24	2,810	825	1,935	1,535	1,945	66	4,670	2,050	2,040	113	2,230	107	1,085	633
	coliform bacteria	[CFU/mL]	87	11	585	215	1,035	420	206	18	1,035	845	115	13	233	49	171	1,650
	standard plate count	[CFU/mL]	5,450	320	2,225	1,280	8,350	595	27,600	2,940	3,550	4,700	8,450	620	21,450	835	2,260	2,660
Removal ratios	E. coli	[%]	99.3		100.0		98.8		100.0		99.2		97.3		97.6		98.4	
	coliform bacteria (chromo)	[%]	98.9		70.6		20.7		96.6		56.1		94.5		95.2		41.7	
	coliform bacteria	[%]	87.9		63.2		59.4		91.5		18.4		89.1		79.2		-864.9	
	standard plate count	[%]	94.1		42.5		92.9		89.3		-32.4		92.7		96.1		-17.7	

COD_{Cr} decreased in many cases as well as SS, though COD_{Cr} of RUN 1, 4, and 7, in which the water temperature was low, increased. COD_{Cr} did not seem to be decomposed by microorganisms because of low temperature, but the reason for the increase is not clear.

Concerning Nitrogen and Phosphorus, there were not obvious differences. NO_3-N increased in almost all cases and Nitrogen was nitrified in experimental process.

Generally, water in the experimental channel was in aerobic condition, and organics tended to be decomposed.

Concerning sanitary indicating bacteria, coliform bacteria and standard plate count were different in each case, although more than 97% of E. coli was removed in all cases. First, comparing RUN 1 (Ave. 9.4℃) and RUN 2 (Ave. 24.5℃) at different temperatures, the removal ratios were 87.9% for coliform bacteria by desoxycholate, 98.9% for coliform bacteria by chromocult, and 94.1% for standard plate count in RUN 1, and were 63.2%, 70.6% and 42.5% in RUN 2. It was reported that coliform bacteria were related to temperature in river investigations (K. Mitarai, 1983), and coliform bacteria increased in physiological salt solution at 20℃ (including a small amount of culture medium), but decreased in that at 4℃ (T. Hatatsu, 1999). The results of this investigation, in which coliform bacteria and standard plate count were at higher temperature, supported the previous finding.

The differences of sanitary indicating bacteria caused by whether chlorine was reduced or not were observed. Comparing RUN 2 with RUN 3, the removal ratios of coliform bacteria by both desoxycholate and chromocult were lower in the chlorine-reduced case (RUN 3). Comparing RUN 4 with RUN 5, the removal ratio of indicating bacteria was lower in the chlorine-reduced case, though the effect of chlorine reduction was not so obvious because of different water temperatures. The differences of removal ratios of indicating bacteria between RUN 4 and RUN 5 were more than the differences between RUN 1 and RUN 2, which were different only in temperature, so the differences between RUN 4 and RUN 5 depended mainly on whether chlorine was reduced or not. However, concerning standard plate counts, the removal ratio of RUN 3 in which chlorine was reduced was more than that of RUN 2, and the standard plate count of RUN 5 increased. The reason for this is not clear.

In the case of gravel with biofilm, the removal ratios of sanitary indicating bacteria except for E. coli were relatively low, and the decomposition of indicating bacteria by biofilm could not be observed. SS after the experiment of RUN 8 was higher than in any other case, and it was thought that the biofilm peeled from the gravel when the water was sampled. As a result, coliform bacteria increased to 10 times and coliform bacteria were thought to attach to SS.

SUMMARY

1) When chlorine disinfected treated wastewater was passed through the experimental channel, sanitary indicators were affected by the water temperature and chlorine reduction. On the other hand, the effects of channel bed, flow rate, and inclination could not be observed in this study.
2) The increase of coliform group could not be observed in this study. The effects of the decrease of coliform group caused by adsorption to gravel or being preyed upon were thought to be greater.
3) The decrease of sanitary indicators in the case of gravel with biofilm could not be observed though such decrease had been expected due to being preyed upon by biofilm. The reason was supposed to be the effect of SS raised from biofilm.

4) The removal ratios of E. coli were more than 97% in any cases.

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