Evaluation of fecal contamination in Tokyo coastal area after CSO events and prevention of waterfront by aquatic filter barrier

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Highlights

- Monitoring 9 sewage markers provides more discussion to explain situation after rainfall events.
- Aquatic filter barrier was found to reduce impact of fecal contamination during a bathing event.

Introduction

Many populated cities such as Tokyo metropolitan are served by combined sewer systems. Under intense rainfall events, Tokyo coastal area are affected by CSO discharge containing pollutants that degrade the water quality (Katayama et al., 2004; Maki et al., 2007). Located in the area is Odaiba seaside park, a famous waterfront area for recreational activities and a venue for triathlon race in Tokyo 2020 Olympic and Paralympic games. Accordingly, the water quality is under high concern and CSO pollution control is urgently required. In that matter, an aquatic filter barrier was installed to prevent fecal contamination in the area during a sea bathing event, namely “Odaiba plage” that was held in August, 2019.

In this study, several types of sewage markers were used to evaluate the impact of contamination. Fecal bacteria including *E. coli* and *enterococcus* were monitored as microbial markers, as well as two types of bacteriophages as viral indicator. PPCPs (Pharmaceuticals and Personal Care Products) were also included as chemical markers, categorizing into labile compounds (acetaminophen: ACE, theophylline: THEO, caffeine: CAF) and conservative compounds (carbamazepine: CBZ, crotamiton: CTMT).

This study aims i) to evaluate the impact of fecal contamination from middle stream of the inflow urban river to Tokyo coastal area located downstream after rainfall events, ii) to investigate the effect of aquatic filter barrier to prevent fecal contamination in Odaiba seaside park during a bathing event, and iii) to describe different behavior of PPCPs as chemical markers in coastal area after rainfall events.

Methodology

Middle stream and Tokyo coastal area monitoring

Surface water samples were collected in 7 locations around Tokyo coastal area and 4 points in Odaiba seaside park as shown in **Figure 1**. Sampling surveys in the coastal area (**Figure 1** (left)) were conducted after two rainfall events on Oct. 19th and Dec. 2nd, 2019 as summarized in **Table 1**. In addition, samples were collected on Oct. 10th, 2018 under dry weather condition.

Tokyo coastal area

Sampling Locations	
KR:	Kanda river mouth
SR:	Sumida river mouth
HD:	Hinode
HM:	Harumi
RB:	Rainbow bridge
OB:	Odaiba seaside park
TT:	Tokyo bay tunnel

CSO sources:
There are more than 700 CSO chambers and 29 pumping stations along Sumida river and its tributary and in the Tokyo

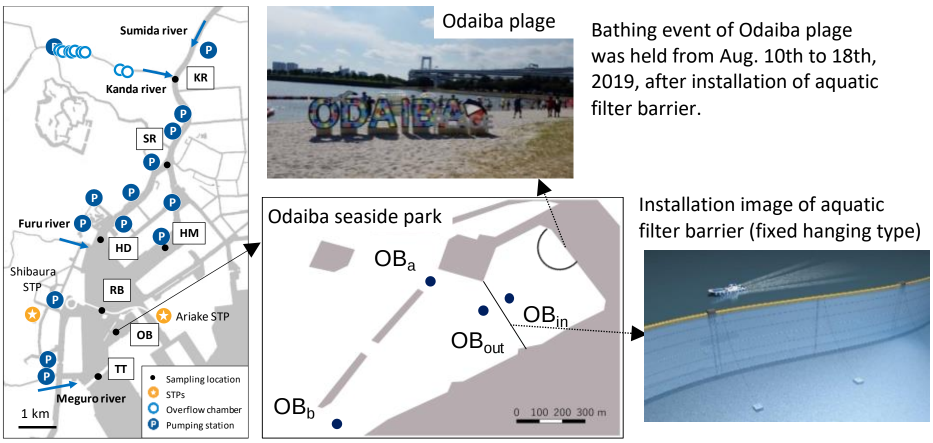


Figure 1. Tokyo coastal area with 7 sampling locations and (left) and Odaiba seaside park installed with aquatic filter barrier (right).

Table 1. Summary of precipitation data and tide level.

Rainfall event	Total precipitation (mm)	Max. rainfall intensity (mm/hr)	Rainfall duration (hr)	Min-max tide level during rainfall (m.T.P.)	Tidal change during rainfall (m)	Lag time before sampling (hr)
Oct. 2019	57	13.5	12 (Oct. 18th – 19th)	(-0.78) – 0.62	1.40	0
Dec. 2019	36	8	8 (Dec. 2nd)	0.17 – 0.52	0.35	17

Odaiba area monitoring during a bathing event

During bathing event (Aug. 10th – 18th, 2019), an aquatic filter barrier made of Polyester fabric was installed in the area. The barrier consisted of a hanging type curtain, a weight and a float. It was hanged from the surface layer to 3-m depth. Surface water samples were collected around Odaiba seaside park area (**Figure 1**(right)) after 3 rainfall events, before and during bathing season, on July 28th (total precipitation = 15 mm), Aug. 14th (8.5 mm) and Aug. 15th (20 mm). Collection was done two times a day covering high and low tide periods on July 28th, Aug. 14th and 17th.

Analysis of PPCPs and microbial indicators

Samples for PPCPs were applied to solid phase extraction (SPE) and quantified by LC/MS/MS technique using Q-Orbitrap mass spectrometry. *E. coli* (EC) was determined using Chromocult® Coliform agar. *Enterococcus* (ENT) was determined using Enterolert test kit in Oct. 2018, Oct. and Dec. 2019 sampling event, while Chromocult® Coliform agar was used in Aug. 2019. F-phage (FPH) was enumerated by single layer agar method using *Salmonella Typhimurium WG49* while Somatic coliphage (SOMCPH) was determined by double agar layer using *E. coli WG5*.

Results and discussion

Middle stream and Tokyo coastal area monitoring

After rainfall events, elevated concentrations of chemical and microbial markers were observed compared to dry weather concentrations as shown in **Table 2**. The whole area was contaminated by CSO pollutants as well as Odaiba seaside park. As for microbial markers, *E. coli* of 2.48 $\log_{10}$(CFU/100mL) at Odaiba was found comparable to dry concentration (2.18 $\log_{10}$(CFU/100mL)) in Oct., while it was elevated in Dec. event, at 4.31 $\log_{10}$(CFU/100mL). On the other hand, other microbial markers were significantly elevated in both events. Even though ENT was 1 log concentration higher than the standard (100 CFU/100mL), *E. coli* was just above standard value of 250 CFU/100mL (2.40 $\log_{10}$(CFU/100mL)). This emphasizes the different behaviour among microbial markers.

Table 2. Concentration ranges of chemical and microbial markers after rainfall events and under dry weather condition.

Chemical/ microbial markers	Unit	Concentrations				
		After rainfall event (Oct. 19th, 2019)		After rainfall event (Dec. 3rd, 2019)		Dry weather (Oct. 10th, 2018)
		Other locations (n=6)	Odaiba	Other locations (n=6)	Odaiba	All locations (n=7)
ACE	ng/L	142 – 410	142	148 – 571	236	23 – 54
THEO		294 – 1,355	294	368 – 898	502	74 – 114
CAF		663 – 3,608	663	663 – 1,694	889	205 – 252
CMZ		7 – 11	8	6 – 15	9	6 – 17
CTMT		71 – 104	84	85 – 294	110	71 – 217
E. coli	$\log_{10}$(CFU/100mL)	2.48 – 4.61	2.48	4.14 – 5.04	4.31	2.00 – 3.22
ENT	$\log_{10}$(MPN/100mL)	1.70 – 4.54	3.18	3.48 – 4.17	3.71	2.04 – 2.79
SOMCPH	$\log_{10}$(PFU/100mL)	2.45 – 4.14	3.37	2.70 – 3.36	3.28	1.48 – 2.18
FPH		2.76 – 4.22	2.91	2.88 – 4.01	3.13	Below DL* – 1.78

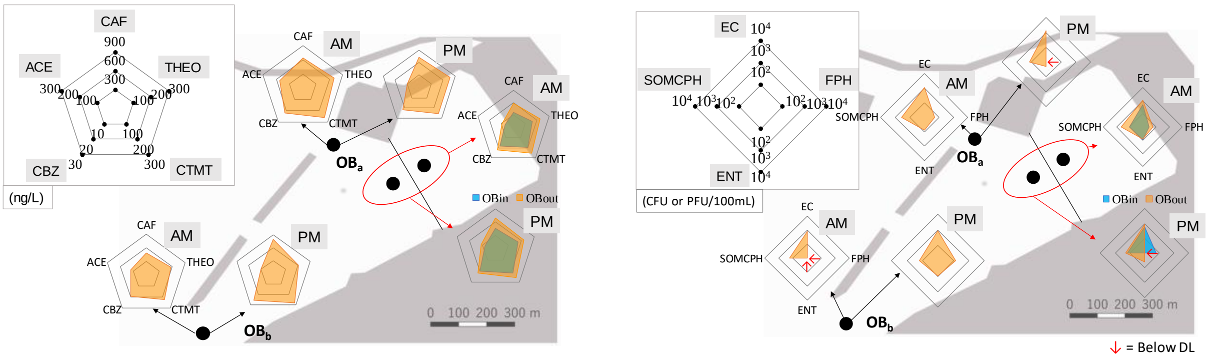
*DL = 10 CFU or PFU/100mL for *E. coli* and bacteriophages and 5 MPN/100mL for *enterococcus*.

Focusing on conservative PPCPs (CBZ and CTMT), their concentrations in Oct. event were comparative to dry concentration levels. It suggests that there was higher dilution by stormwater. Salinity level was lower (0.7 – 17.6 PSU) compared to Dec. event (16.5 – 28.3 PSU) supporting the notion. On the other hand, elevated concentrations were observed for labile PPCPs (ACE, THEO and CAF). This was attributed to their different removal during activated sludge process. The labile PPCPs have high influent concentrations but low in effluent, while it was comparable for conservative PPCPs due to their low removal efficiency (Nakada et al., 2006). The different concentration levels should be discussed with consideration of different tidal change and lag time before sampling because labile PPCPs are susceptible to biodegradation and photolysis, while conservative PPCPs were highly dependent on effluent discharge.

Odaiba area monitoring during a bathing event

Figure 2 shows monitoring data of surface water in the morning (AM) and afternoon (PM) on Aug. 17th. Elevated concentrations were observed under influence of rainfall events on Aug. 14th (8.5 mm) and Aug. 15th (20 mm). Focusing on high tide (AM), higher concentrations at OB_a suggested the inflow of polluted water into the Odaiba area through the upper opening channel. Concentrations of some markers decreased when low tide came (PM). The reduction of ACE and F-phage from AM to PM was possibly attributed to strong sunlight intensity with average of 668.2 W/m^2 during the daytime. Sunlight exposure experiments using a simulator shows the susceptibility of ACE to light with half-life time as fast as 6.7 hrs at average light intensity of 315.8 W/m^2, while other PPCPs reduced at lower rate. In addition, F-phage was also more sensitive to sunlight than other microbes. Comparing between inside and outside of the barrier, *E. coli* was lower by 0.35 $\log_{10}$(CFU/100mL) at high tide (AM) as well as both bacteriophages. All PPCPs were also lower inside, confirming the preventive effect of the barrier on fecal contamination.

However, the contamination impact on Aug. 17th was not so significantly noticed, likely because the sampling was conducted 1.5 days after the rainfall on Aug. 15th. The sewage maker concentrations were affected by several processes such as dilution and sunlight degradation/inactivation after the rainfall.



*DL = 10 CFU/100mL for *E. coli* and *enterococcus*, and 10 PFU/100mL bacteriophages.

Figure 2. Concentrations of PPCPs (left) and microbial markers (right) in Odaiba area on Aug. 17th (during bathing event). Total precipitation was 20 mm. on Aug. 15th. (AM: high tide (WL= 0.89 – 0.35 m. T.P.); PM: low tide (WL= (-0.72) – (-0.42) m. T.P.))

Conclusions and future work

This study monitored multiple types of sewage markers in Tokyo coastal area after rainfall events. The impact of fecal contamination was discussed considering different behaviour of nine markers. The effectiveness of the installed aquatic filter barrier to prevent fecal contamination during a bathing event was evaluated and evidenced by the decreased level of markers inside. Monitoring data also suggests different degradation/inactivation rate among the markers after rainfall event. Multiple maker evaluation provides better understanding of fecal contamination behaviour. On the other hand, effect of sunlight in coastal water on the makers should be determined in the future. Since this work is a one-time samples collection, more sampling campaigns should be conducted during the bathing event. Furthermore, water quality model simulation should be considered to quantitatively comprehend the situation in coastal area.

References

Katayama, H., Okuma, K., Furumai, H., and Ohgaki, S. (2004). Series of surveys for enteric viruses and indicator organisms in Tokyo Bay after an event of combined sewer overflow. Water Science and Technology, 50(1), 259–262.

Maki, H., Sekiguchi, H., Hiwatari, T., Koshikawa, H., Kohata, K., Yamazaki, M., … Watanabe, M. (2007). Influences of Storm Water and Combined Sewage Overflow on Tokyo Bay. Environmental Forensics, 8(1–2), 173–180.

Nakada, N., Tanishima, T., Shinohara, H., Kiri, K., and Takada, H. (2006). Pharmaceutical chemicals and endocrine disrupters in municipal wastewater in Tokyo and their removal during activated sludge treatment. Water Research, 40(17), 3297–3303.