Health risk monitoring and management for sustainable urban environment

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Tokyo bay monitoring

Combined sewer overflow
increase viruses in water
Tokyo Metropolitan district has 30,000,000 people. Mainly covered with combined sewer.
Combined sewer systems (CSS) are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe.
What is CSO?

Combined Sewer Overflow

Dry weather

Wet weather
Importance of Pathogens in CSO

- Microbial risk is accumulation of daily risk, which cause acute disease.
- Chemical water quality standard is based on chronic disease.
- Chemical contamination level varies linearly but microbial level exponentially. In the extreme event microbial risk should be cared.
Tokyo Olympic Games 2020

- Triathlon at Odaiba Beach
- Water quality standard: $E. \text{coli} < 250 \text{cfu/100ml}$

Triathlon competition (Aug 2010 in Copenhagen, Denmark) held shortly after a CSO resulted in an outbreak (Andersen et al. 2013).
Virus survey in Tokyo bay

- Date…2004 Aug 4 ~ Oct 15
- Samples…47times each for 3 location, collected in the morning
- Parameters…Norovirus, Adenovirus, Total coliforms, *E. coli*
  - Volume used for virus concentration : 1,000mL

![Map of sampling sites](image-url)
Virus detection procedure

Wastewater (100 or 1,000mL) → Concentration using MgCl₂ method (Katayama et al. 2002)

Concentrate (10mL) → Ultrafiltration using Centriprep YM-50 (twice)

Reconcentrate (700µL) → RNA extraction 140µL

RNA (60µL) → Reverse transcription

RNA (60µL) → TaqMan PCR

DNA (200µL) → DNA extraction 200µL

DNA (200µL) → TaqMan PCR

5µL x 3 → cDNA (120µL)

5µL x 3 → AdV

cDNA and DNA were diluted with MilliQ water by serial 10-fold dilution and applied to detection of NV, EV, and AdV.
Profile of Total coliforms and *E. coli*

- Increased after rain event, gradually decrease for several days.
- Increase on Sep 4 (rain: 84.5mm)
  - Total coliforms...1.55 log
  - *E. coli*...2.22 log
Profile of Norovirus and Adenovirus

- Virus also increased by rain event
- Decrease rate of viruses were less than those of coliforms.

Infection risk was shown to be higher for a few days after rain.
Materials and Methods (Sampling site)

- **Sumida**
  - Mouth of Sumida river
- **Meguro**
  - Mouth of Meguro river
- **Sea Lane**
  - Regularly used route for vessels
- **Odaiba**
  - Port, Inlet
Materials and Methods

- Water samples were collected at three different depths (0.5, 3 and 5 m) at 4 sites, using a special sampling device.
Materials and Methods

◆ Water samples were collected from Tokyo Bay on 1, 2, 3, 5, 8, 13 days after the first rainfall observed in June 2014.

<table>
<thead>
<tr>
<th>Date (June)</th>
<th>6&lt;sup&gt;th&lt;/sup&gt;</th>
<th>7&lt;sup&gt;th&lt;/sup&gt;</th>
<th>8&lt;sup&gt;th&lt;/sup&gt;</th>
<th>10&lt;sup&gt;th&lt;/sup&gt;</th>
<th>13&lt;sup&gt;th&lt;/sup&gt;</th>
<th>18&lt;sup&gt;th&lt;/sup&gt;</th>
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<tbody>
<tr>
<td>Sumida</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Meguro</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Sea Lane</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
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<tr>
<td>Odaiba</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>×</td>
<td>○</td>
</tr>
</tbody>
</table>

Total rainfall amount 247 mm

The rainfall profile and timing of sample collection.
Result

Norovirus GI at Odaiba

* : Detection efficiency was lower than 10%.
↓ : Under detection limit
Results of all samples
The high concentration of E. coli is a clear evidence of CSO.

Impact of CSO on virus occurrence was not clear.
Results of Sea Lane samples

Upper 0.5m

Middle 3m

Lower 5m
Summary
◆ Concentrations of *E. coli* were higher at upper layer on the first day, and clearly decreased during the sampling period (18 days).

◆ PMMoV stayed high concentration throughout the sampling period.

◆ Fluctuations of PMMoV and NoVs concentrations are limited, and impact of CSO seems limited.
⇒ Maybe because of too heavy rain?
A Rapid Coagulation Treatment during wet weather period
Need of Compact Treatment for municipal wastewater

- Most of the treatment systems were developed assuming ordinal condition
- Impact of extreme events (Rainfall, Electricity shortage, Tsunami) should be taken into account.
Need of Tentative treatment

- No established treatment system before full recovery of WWTPs.
- What should be prioritized?
  - BOD, N, P
  - Pathogens,
  - Heavy metals, Chemcals
- Should consider the receiving water body
Reducing CSO problem

*Under wet weather condition*

Combined Sewer Overflow

Combined Sewer System

**Primary treatment should be more developed.**
Disinfection of Pathogens in Wastewater

**Chlorination in WWTPs**
- Effective for E. coli and coliforms (Tree et al., 2003)
- Not effective against bacteriophages under high ammonium condition (Tree et al., 2003, 2005; Armon et al., 2007)
- Factors: pH, ammonia, SS, Organic Matter

**UV irradiation**
- Effective to all microbes
- Easy maintenance
- Factors: UV absorbance

Problem may be caused by the use of coliforms as the single microbial indicator in the water management
Coagulants

- Chitosan: as a cheap material in local use in developing country
- **Al**: Used worldwide. Some concern in residual Al on health issues.
- **Fe**: Seawater lacks Fe for ecosystem good performance of coagulation
  - Polyferrite: Effective for Odor treatment Used in the wastewater industry
  - Obtained from Iron industry
Objective

Development and Evaluation of Compact treatment of wastewater using polyferrite

- Efficiency as treatment of pathogens are evaluated using E. coli, coliforms and bacteriophages as indicators.
- Several sets of condition of Coagulation/Chlorination
- UV absorbance was also measured to assess the effectiveness of UV treatment

Bacteriophages were used as the indicator of enteric viruses

Indegenous microbes were evaluated
Rapid 60

Slow 60
Disinfection study

- PolyFe was selected due to good removal of phages.

Diagram:
- Influent
  - Coagulant
  - Mix 3min
  - Settle 27min
  - Decantation
  - Chlorine
### Coagulation condition

<table>
<thead>
<tr>
<th>Coagulation</th>
<th>PolyFe Dose (mg/L)</th>
<th>2sec Rapid mixing*</th>
<th>3min Slow mixing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slow 60</td>
<td>60</td>
<td>×</td>
<td>○</td>
</tr>
<tr>
<td>Rapid 60</td>
<td>60</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

*: Spike coagulant before pump up ⇒ 2 sec rapid mixing

### Chlorination

Chlorine dose: 5mg/L, 10mg/L

Contact time: 1min, 5 min, 30 min
• **PolyFe dose at 60mg/L** most effectively removed all indicators.
Absorbance after treatment

- E260 decreased by the PolyFe treatment especially by Rapid 60
- UV treatment may be effective after the treatment.

(N=6. Error bar: SD)
Conclusion

1. Rapic mixing enhanced the treatment efficiency even a short time (2 sec)
2. PolyFe dose at 60mg/L achieved most effective removal of all indicators tested.
3. Supernatant of the treated water at 60mg/L with rapid mixing had low E260.
4. Coagulation may be a good option to treat combined sewer in a short retention time.
Acknowledgement

- Miyagi Prefecture,
- Ministry of Land, Infrastructure, Transport and Tourism
- Ministry of Environment
- AGS, University of Toyo
- Steel Foundation for Environmental Protection Technology
Discussions

Comparing the diffusion of viruses and *E. coli* (Upper / lower layer ratio of concentrations)
Discussions

Comparing the diffusion of viruses and *E. coli* (Upper / lower layer ratio of concentrations)

- *E. coli* showed relatively high ratio on the first day compared with the viruses.
- Fluctuations of the viruses stayed within a narrow range during CSO event compared with *E. coli*.

- Pollution dynamics of indicator bacteria and viruses may reflect their different behaviors in diffusion and settling after CSO events.
Methodology

Raw sewage water collected from wastewater treatment plant in Kanto area, Japan (stored at 4°C)

Perform the coagulation process by using Jar-test with
1. Polyaluminium chloride (PAC);
   dose 15, 30 and 60 mg/L
2. Polyferric sulphate (PF);
   dose 10, 30, 60 and 90 mg/L
3. Chitosan (CT);
   dose 5, 10 and 30 mg/L
   ➢ Mixing speed: 1200 rpm
   ➢ Mixing time: 2 sec. and 20 sec.
   ➢ Settling time: 10 mins

➢ Physico-chemical test
  ▪ pH
  ▪ SS
  ▪ Turbidity
  ▪ UV254
  ▪ BOD5

➢ Biological test
  ▪ E.coli and total coliform
  ▪ Bacteriophage
    ✓ F-specific phage
    ✓ Somatic phage
Outline of Treatment

Influent

Mix 3min

Settle 27min

Water quality test
## Samples used

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>2011/9/29</td>
<td>Miyagi</td>
<td>Influent, Primary treated, effluent</td>
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<tr>
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<td>Kanto</td>
<td>Influent, Primary treated,</td>
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<td>2012/1/11</td>
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</tr>
<tr>
<td>1/27</td>
<td>Miyagi</td>
<td>Influent, Primary treated, effluent</td>
</tr>
</tbody>
</table>
Removal of Indicators in WWTP (Miyagi)

- **Phages** remain and not inactivated effectively
- **E. coli and coliforms** were reduced by the treatment

![Graph showing remaining ratio of E. coli, Coliforms, F-phages, and Somatic Coliphages](graph.png)

(N=4. Error bar: max-mean, mean-min)
Rapid mixing (2 sec) enhanced the treatment efficiency.
Result and discussion: SS and BOD5

- Coagulation process has effectively removed the BOD and SS from wastewater.
- Coagulation with PAC and PF at optimized condition (PAC 15, PAC 30, PF 60, and PF 90 mg/L) can remove high particles.
- From this point, microorganisms which is attached to SS particles were also removed together by coagulation process.
- The BOD value was low when the SS is less.

** BOD and SS was set as a technical practice for company by wastewater works at BOD 40-70 mg/L and SS at 70 mg/L.

Fig. 1 The amount of sludge after coagulation (N=5)
Result and discussion: Sludge production

- Sludge production are inverse variation to turbidity.
- The use of PAC and PF at high dose has higher amount of sludge than the use of chitosan.
- PAC and PF has high Electrical charge provide the chance to bind with other particles than CT.
- After the coagulation process and sedimentation process. The sludge treatment will considered.

Amount of sludge after coagulation (N=5)
Result and discussion: *E. coli* and total coliform

- This Fig. shows the relationship between the remaining of *E. coli* and total coliform.
  - *E. coli* and total coliform were removed by coagulation with PAC60 mg/L by 3 log.
  - And PF90 mg/L can also remove *E. coli* and total coliform by 3 log.
  - Coagulation with CT at various dose are not effectively remove both *E. coli* and total coliform.

Fig. 3 The correlation between the log remaining of *E. coli* and total coliform (N=5)
Result and discussion: Bacteriophage (somatic phage and F-phage)

![Graph showing the relationship between bacteriophage, somatic phage, and F-specific phage.]

- This Fig. shows the relationship between the remaining of bacteriophage, somatic phage, and F-specific phage.

- *E. coli* and total coliform were removed by coagulation with **PAC 60 mg/L** by 3 log.
- Coagulation with **PF 90 mg/L** can also remove *E. coli* and total coliform by 3 log.
- Coagulation with **CT** at various dose are not effectively remove both *E. coli* and total coliform.