Comprehensive Management of Water Environment and Sewage Works

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Professor emeritus, Kyusyu Kyoritsu University,
Fukuoka, Japan
Contents

1. Comprehensive measures against environmental pollution
2. Classification of water system
3. Sewage works in river basin
4. Needs of nitrogen and phosphorus removal
5. Sewage works in lake basin
6. Regulation concept of pollutants
1. Comprehensive measures against environmental pollution

( Monitoring of environment, Establishment of regulation Laws against pollutants )

- Monitoring of environment, Establishment of regulation Laws against pollutants
- Standards for drinking water (217 substances)
  - Basic parameters……..50
  - Distinct toxic substances…127 (agrichemicals of 101 are included)
  - Indistinct toxic chemicals… 40
- Environmental quality standards related to
  *the protection of living environment:
    BOD, COD, N, P
  *the protection of human health:
    Harmful substances of 26
- Standards of drinking water
- Standards of fertilizer
- In 1947: Food Sanitation Law
- In 1970’s, observation points: 6,000
- In 1991: Standards of soil contamination
  (Harmful substances, except nitrogen)
- In 1997: Standards of groundwater pollution
  (Harmful substances including nitrogen)
- In 2002: Regulation Law Against Soil Contamination
- In 2003: Food Safety Basic Law
- Human activity (consumption & production)
- Drinking Water
- Water Supply Plant
  - Standards for drinking water (217 substances)
    - Basic parameters……..50
    - Distinct toxic substances…127 (agrichemicals of 101 are included)
    - Indistinct toxic chemicals… 40
- Wastewater Treatment Plant
  - Effluent standards:
    Harmful substances, BOD, COD, N, P
- Water Environment
  - Rivers
  - Lakes
  - Coastal waters
    - Environmental quality standards related to
      *the protection of living environment:
        BOD, COD, N, P
      *the protection of human health:
        Harmful substances of 26
    - Since 1970’s, observation points: 6,000
- Soil Environment
  - Leakage of harmful substances into soil environment
  - Sludge
  - Compost
  - Standards of fertilizer
    - Harmful substances
- Groundwater Environment
  - Groundwater pollution
  - Observation well: 1,000
- In 1997: Standards of groundwater pollution
  (Harmful substances including nitrogen)
- In 2002: Regulation Law Against Soil Contamination
- In 2003: Food Safety Basic Law
- Farm/stockbreeding/marine products
  - observation well: 1,000
### Environmental quality standards for conservation of the living environment

#### 1. Rivers (excluding lakes)

<table>
<thead>
<tr>
<th>Item class</th>
<th>Water use</th>
<th>Standard value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AA</td>
<td>Water supply class 1, conservation of natural environment, and uses listed in A-E</td>
<td>6.5 ≤ pH ≤ 8.5</td>
</tr>
<tr>
<td>A</td>
<td>Water supply class 2, fishery class 1, bathing and uses listed in B-E</td>
<td>6.5 ≤ pH ≤ 8.5</td>
</tr>
<tr>
<td>B</td>
<td>Water supply class 3, fishery class 2, and uses listed in C-E</td>
<td>6.5 ≤ pH ≤ 8.5</td>
</tr>
<tr>
<td>C</td>
<td>Fishery class 3, industrial water class 1, and uses listed in D-E</td>
<td>6.5 ≤ pH ≤ 8.5</td>
</tr>
<tr>
<td>D</td>
<td>Industrial water class 2, agriculture water, and uses listed in E</td>
<td>6.0 ≤ pH ≤ 8.5</td>
</tr>
<tr>
<td><strong>C</strong></td>
<td>Industry water class 3 and conservation of environment</td>
<td>6.0 ≤ pH ≤ 8.5</td>
</tr>
</tbody>
</table>

#### 2. Lakes (natural lakes and reservoirs that have 10 million cubic meters of water or more)

<table>
<thead>
<tr>
<th>Item class</th>
<th>Water use</th>
<th>Standard value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AA</td>
<td>Water supply class 1, fishery class 1, conservation of natural environment, and uses listed in A-C</td>
<td>6.5 ≤ pH ≤ 8.5</td>
</tr>
<tr>
<td>A</td>
<td>Water supply classes 2 and 3, fishery class 2, bathing, and uses listed in B-C</td>
<td>6.5 ≤ pH ≤ 8.5</td>
</tr>
<tr>
<td>B</td>
<td>Fishery class 3, industrial water class 1, agricultural water, and uses listed in C</td>
<td>6.5 ≤ pH ≤ 8.5</td>
</tr>
<tr>
<td><strong>C</strong></td>
<td>Industrial water class 2 and conservation of the environment</td>
<td>6.0 ≤ pH ≤ 8.5</td>
</tr>
</tbody>
</table>

#### B

<table>
<thead>
<tr>
<th>Item class</th>
<th>Water use</th>
<th>Standard value</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Conservation of natural environment and uses listed in II-V</td>
<td>≤ 0.1 mg/L</td>
</tr>
<tr>
<td>II</td>
<td>Water supply classes 1, 2, and 3 (except special types), fishery class 1, bathing, and uses listed in III-V</td>
<td>≤ 0.2 mg/L</td>
</tr>
<tr>
<td>III</td>
<td>Water supply class 3 (special types) and uses listed in IV-V</td>
<td>≤ 0.4 mg/L</td>
</tr>
<tr>
<td>IV</td>
<td>Fishery class 2 and uses listed in V</td>
<td>≤ 0.6 mg/L</td>
</tr>
<tr>
<td>V</td>
<td>Fishery class 3, industrial water, agricultural water, and conservation of the environment</td>
<td>≤ 1 mg/L</td>
</tr>
</tbody>
</table>
### 3. Coastal Waters

#### A

<table>
<thead>
<tr>
<th>Item class</th>
<th>Water use</th>
<th>Standard value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Fishery class 1, bathing, conservation of the natural environment, and uses listed in B-C</td>
<td>Hydrogen-ion concentration (pH): $7.8 \leq \text{pH} \leq 8.3$, Chemical oxygen demand (COD) $\leq 2 \text{ mg/L}$, Dissolved oxygen (DO) $\geq 7.5 \text{ mg/L}$, Total coliform $\leq 1,000 \text{ MPN/100 mL}$, N-hexane Extract (oil, etc.) Not detectable</td>
</tr>
<tr>
<td>B</td>
<td>Fishery class 2, industrial water and the uses listed in C</td>
<td>Hydrogen-ion concentration (pH): $7.8 \leq \text{pH} \leq 8.3$, Chemical oxygen demand (COD) $\leq 3 \text{ mg/L}$, Dissolved oxygen (DO) $\geq 5 \text{ mg/L}$, Total coliform —, N-hexane Extract (oil, etc.) Not detectable</td>
</tr>
<tr>
<td>C</td>
<td>Conservation of the environment</td>
<td>Hydrogen-ion concentration (pH): $7.0 \leq \text{pH} \leq 8.3$, Chemical oxygen demand (COD) $\leq 8 \text{ mg/L}$, Dissolved oxygen (DO) $\geq 2 \text{ mg/L}$, Total coliform —, N-hexane Extract (oil, etc.) Not detectable</td>
</tr>
</tbody>
</table>

#### B

<table>
<thead>
<tr>
<th>Item class</th>
<th>Water use</th>
<th>Standard value</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Conservation of the natural environment and uses listed in II-IV (except fishery classes 2 and 3)</td>
<td>Total nitrogen $\leq 0.2 \text{ mg/L}$, Total phosphorus $\leq 0.02 \text{ mg/L}$</td>
</tr>
<tr>
<td>II</td>
<td>Fishery class 1, bathing, and the uses listed in III-IV (except fishery classes 2 and 3)</td>
<td>Total nitrogen $\leq 0.3 \text{ mg/L}$, Total phosphorus $\leq 0.03 \text{ mg/L}$</td>
</tr>
<tr>
<td>III</td>
<td>Fishery class 2 and the uses listed in IV (except fishery class 3)</td>
<td>Total nitrogen $\leq 0.6 \text{ mg/L}$, Total phosphorus $\leq 0.05 \text{ mg/L}$</td>
</tr>
<tr>
<td>IV</td>
<td>Fishery class 3, industrial water, and conservation of habitable environments for marine biota</td>
<td>Total nitrogen $\leq 1 \text{ mg/L}$, Total phosphorus $\leq 0.09 \text{ mg/L}$</td>
</tr>
</tbody>
</table>
Designation of water body classes on rivers in Fukuoka urban area
Present state of river water quality in Fukuoka prefecture (2009)

○: Rivers (regulation parameter : BOD)
□: Lakes or reservoirs (regulation parameter : COD)
○、□: environmental standard is unachieved
Figure 1 Trends in achievement of BOD/COD environmental standards

Remarks
1. BOD for rivers and COD for lakes and seas
2. Achievement rate (%) = (The number of water areas meeting the standards / The number of water areas applicable) × 100

Source: Measurement results of the quality of public water areas in fiscal 2004, Ministry of the Environment
<table>
<thead>
<tr>
<th>Measurement item</th>
<th>Number of points surveyed</th>
<th>Number of points not meeting the standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadmium</td>
<td>4,587</td>
<td>0</td>
</tr>
<tr>
<td>Total cyanide</td>
<td>4,182</td>
<td>0</td>
</tr>
<tr>
<td>Lead</td>
<td>4,703</td>
<td>5</td>
</tr>
<tr>
<td>Chromium(VI)</td>
<td>4,312</td>
<td>0</td>
</tr>
<tr>
<td>Arsenic</td>
<td>4,688</td>
<td>20</td>
</tr>
<tr>
<td>Total mercury</td>
<td>4,527</td>
<td>0</td>
</tr>
<tr>
<td>Alkyl mercury</td>
<td>1,412</td>
<td>0</td>
</tr>
<tr>
<td>PCBs</td>
<td>2,443</td>
<td>0</td>
</tr>
<tr>
<td>Dichloromethane</td>
<td>3,690</td>
<td>1</td>
</tr>
<tr>
<td>Tetrachloroethylene</td>
<td>3,709</td>
<td>0</td>
</tr>
<tr>
<td>1,2- Dichloroethane</td>
<td>3,685</td>
<td>1</td>
</tr>
<tr>
<td>1,1-Dichloroethylene</td>
<td>3,670</td>
<td>0</td>
</tr>
<tr>
<td>cis-1,2- Dichloroethylene</td>
<td>3,673</td>
<td>0</td>
</tr>
<tr>
<td>1,1,1-Trichloroethane</td>
<td>3,718</td>
<td>0</td>
</tr>
<tr>
<td>1,1,2-Trichloroethane</td>
<td>3,670</td>
<td>0</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>3,635</td>
<td>0</td>
</tr>
<tr>
<td>Tetrachloroethylene</td>
<td>3,637</td>
<td>0</td>
</tr>
<tr>
<td>1,3-Dichloropropene</td>
<td>3,731</td>
<td>0</td>
</tr>
<tr>
<td>Thiram</td>
<td>3,658</td>
<td>0</td>
</tr>
<tr>
<td>Simazine</td>
<td>3,848</td>
<td>0</td>
</tr>
<tr>
<td>Thiobencarb</td>
<td>3,854</td>
<td>0</td>
</tr>
<tr>
<td>Benzone</td>
<td>3,832</td>
<td>0</td>
</tr>
<tr>
<td>Selenium</td>
<td>3,861</td>
<td>0</td>
</tr>
<tr>
<td>Nitrate-N and nitrite-N</td>
<td>4,274</td>
<td>4</td>
</tr>
<tr>
<td>Fluorine</td>
<td>3,907</td>
<td>11</td>
</tr>
<tr>
<td>Boron</td>
<td>2,863</td>
<td>0</td>
</tr>
<tr>
<td>Total (number of monitoring points)</td>
<td>5,703 (5,708)</td>
<td>42 (41)</td>
</tr>
<tr>
<td>Environmental standards achievement rate</td>
<td>99.3% (99.3%)</td>
<td></td>
</tr>
</tbody>
</table>

Notes
1. Numbers in parentheses are the results for fiscal 2003.
2. As for fluorine and boron, the points surveyed do not include seas, and rivers/lakes where the standards were not met due to the influence of seawater.
3. The total number of points not meeting the standards is an actual number; a point where more than two items of the standards are not met is counted as one non-conforming point. In fiscal 2004, there was one point where two items of the standards were not met.
Standards related to conservation of human health

<table>
<thead>
<tr>
<th>Toxic Substances</th>
<th>WTP Effluent Standard</th>
<th>Environmental quality standard</th>
<th>Drinking Water</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mg/L</td>
<td>mg/L</td>
<td>mg/L</td>
</tr>
<tr>
<td>Alkyl - mercury</td>
<td>ND</td>
<td>ND</td>
<td>-</td>
</tr>
<tr>
<td>Total - mercury</td>
<td>0.005</td>
<td>0.0005</td>
<td>0.0005</td>
</tr>
<tr>
<td>Cd (cadmium)</td>
<td>0.1</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Pb (lead)</td>
<td>0.1</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Organic phosphorous compound</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cr (chromium)</td>
<td>0.5</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>As (arsenic)</td>
<td>0.1</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>CN (cyanogen)</td>
<td>1</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>NO₃-N, NO₂-N</td>
<td>100</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

- Organic chloride compounds and agrichemicals are added to the table (total: 26-28 substances)
- Environmental Quality Standard = 1/10(Effluent Standard) = Drinking Water Standard
- Purification plant does not remove these harmful chemicals.
- It is assumed that the effluent discharged from WTP is diluted to one-tenth in/by public water body.
Recommended nitrogen concentrations for water use

**Nitrogen mg/L**

- **Drinking water**
  - Total NO\(_x\)-N(NO\(_3\)-N + NO\(_2\)-N) < 10 mg/L
  - (as harmful chemicals)

- **Irrigation for paddy field (example 1)**
  - T-N 7 mg/L

- **Irrigation for paddy field (example 2)**
  - T-N 5 mg/L, NH\(_4\)-N 3 mg/L

- **Observed T-N concentration range at down stream of relatively polluted river in Japan**
  - 2 mg/L

- **Standard for irrigation water**
  - T-N 1 mg/L

- **Drinking water**
  - NH\(_4\)-N 0.1 mg/L (Upper limit for preventing high dosage of chlorine)
2. Classification of water system

Discharge to closed sea area

Discharge to river, Multiple use of water

Discharge to lake
3. Sewage works in river basin (Control of BOD)

For water quality conservation
900 m²/person
= 3Q₀

Dilution Effect

For water supply 300 m²/person
= Q₀ (300 L/person/day)

BOD 0.5 mg/L

BOD 2.9 mg/L (reusable)

Wastewater treatment plant: 95% removal

\[
2.9 = \frac{0.5 \times 3Q₀ + 10 \times Q₀}{3Q₀ + Q₀}
\]

Excrete BOD: 60g/person/day

Water supply

Original design: Dr. TANBO
Stream Flow Conditions

- **a. plentiful water-discharge (95-day discharge)**
- **b. ordinary water-discharge (185-day discharge)**
- **c. low water-discharge (275-day discharge)**
- **d. droughty water-discharge (355-day discharge)**

(Charts and graphs showing flow rates over different days and years, with labels for each condition.)
Water right

Given water right
(The permission will be renewed every ten years.)

Objectives of river maintenance flow rate

1. "動植物の生息地または育種地の状況"および"漁業"からの必要流量
   For ecological system (fishes, plant life, bird life, etc.)
2. "景観"からの必要流量
   Landscape
3. "流水の清潔の保持"からの必要流量
   Water pollution control
4. "舟運"からの必要流量
   Water use for shipping
5. "塩害の防止"からの必要流量
   Land pollution control to salt-damage
6. "河口の閉塞の防止"からの必要流量
   For preventing of river-mouth clogging
7. "河川管理施設の保護"からの必要流量
   For protection of river facilities
8. "地下水位の維持"からの必要流量
   Maintenance of ground-water level
BOD runoff related to population density

River ONGA
- Basin area: 1,030 km²
- Length of main stream: 61 km
- Average flow at downstream: 30 m³/sec

River GOHSHI
- Basin area: 205 km²
- Length of main stream: 46 km
- Average flow at downstream: 5 m³/sec
- Number of Cattle: 53,000
- Number of Hog: 38,000
- Nitrogen load of livestock: 1.5 million person equivalent

River CHIKUGO
- Basin area: 2,860 km²
- Length of main stream: 143 km
- Average flow at downstream: 75 m³/sec

Nitrogen load of livestock:
- River CHIKUGO: 1.5 million person equivalent
Population density – BOD concentration

Population density, person/km²
4. Needs of advanced wastewater treatment (Nitrogen and Phosphorus Removal)  
Kunmig Lake, Yunnan, China

Eutrophication
Lake Tai, China
5. Sewage works in lake basin (Control of nutrients)

Dilution effect will not be expected.

Water quality standard of lake

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-N</td>
<td>0.2-2 mg/L</td>
</tr>
<tr>
<td>T-P</td>
<td>0.01-0.2 mg/L</td>
</tr>
</tbody>
</table>

Target effluent standards of Lake BIWA are:
- COD =3 mg/L
- T-N=3 mg/L
- T-P=0.02 mg/L

Excrete BOD 60 g/person/day
- T-N 11 mg/L
- T-P 1.3 mg/L

Conventional advanced wastewater treatment:
(for closed sea area) T-N=5~10 mg/L, T-P=0.5~1 mg/L

Water use category 2 in Lake-standards:
- T-N 0.2 mg/L
- T-P 0.01 mg/L
- COD 3 mg/L
Lake BIWA

Water quality standards for Lake BIWA

T-N 0.2 mg/L (Actual value observed: 0.3-0.4)
T-P 0.01 mg/L (Actual value observed: 0.01-0.02)
Nutrients concentrations in river water

Second grade class of Lake-standards

T-N 0.2 mg/L (actual:0.3-0.4)
T-P 0.01 mg/L (actual:0.01-0.02)

Observed water quality in river

T-N 0.2-2 mg/L
T-P 0.01-0.2 mg/L

River A

River B
Nutrients runoff related to livestock densely

N&P Loading rate
( g/person/day, g / Hog or Cattle /day )

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Man</td>
<td>11</td>
<td>1.3</td>
</tr>
<tr>
<td>Hog</td>
<td>40</td>
<td>25</td>
</tr>
<tr>
<td>Cattle</td>
<td>290</td>
<td>50</td>
</tr>
</tbody>
</table>
Characteristic of nutrients runoff in river basin

Influence of farming

- Onga Up St.
- Chikugo Up St.
- Onga Middle St.
- Chikugo Middle St.
- Onga Down St.
- Chikugo Down St.

Influence of livestock

- Gohshi St.
- Down St. of Onga River

Farming area/Basin area (%) vs. NO₃-N (mg/L)

PO₄-P (mg/L) vs. NO₃-N (mg/L)
### 6. Regulation concept of pollutant
(in consideration for the characteristic of water body)

<table>
<thead>
<tr>
<th>Closed water body (Sea, Lake )</th>
<th>River</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water Use</strong></td>
<td></td>
</tr>
<tr>
<td>Sea water : Indirect use</td>
<td>Direct, Multi purpose</td>
</tr>
<tr>
<td>Lake water : Direct, Multi purpose</td>
<td></td>
</tr>
<tr>
<td><strong>Regulation Parameter</strong></td>
<td></td>
</tr>
<tr>
<td>Objective : prevention of eutrophication</td>
<td>BOD</td>
</tr>
<tr>
<td>T-N, T-P, COD</td>
<td>(NH₄-N, NO₃-N : When nitrogen pollution is severe)</td>
</tr>
<tr>
<td><strong>Regulation Concept and Unit</strong></td>
<td></td>
</tr>
<tr>
<td>➢ Total pollutant load regulation</td>
<td>➢ Concentration regulation according to the water usage</td>
</tr>
<tr>
<td>➢ Unit : ton/year</td>
<td>➢ Unit : mg/L</td>
</tr>
<tr>
<td>Annual 75% value : mg/L</td>
<td>Daily average : mg/L</td>
</tr>
</tbody>
</table>
Conclusion

Sustainable Development

Basic Requirement for Environment

Monitoring of Environment,
Establishment of Regulation Laws Against Pollutants for:
- Elimination of harmful/toxic substances from our environment
- Protection of human health
- Conservation of water-environment
- Conservation of soil-environment
- Food safety against various environmental pollutants