River water quality improvement and economics of soft interventions in the Yamato-gawa River basin

Yoshiaki TSUZUKI (Shimane University, Japan)
Minoru YONEDA (Kyoto University, Japan)
Yamato-gawa River basin

(Original source: Physical map of the world, April 2005)
Legends
Monitoring point
River section S.1
Drainage area 10 km
Kyoto Prefecture
Nara Prefecture
Osaka Prefecture
Wakayama Prefecture
Hyogo Prefecture
Osaka Bay

1. Kami-toda-bashi Bridge
4. Kunitoyo-bashi Bridge
5. Kawachi-bashi Bridge
3. Asaka Water Intake
2. Miyuki-bashi Bridge
7. Oriono-bashi Bridge

1,070 km²
2 M people

26 Sep 2011
Yoshiaki Tsuzuki
Background

• Yamato-gawa River is one of the worst water quality rivers among 166 first-class rivers in Japan.

• BOD concentration of the river had been nominated in the worst three rivers since 1972.

• Because of hard interventions (i.e. WWTPs, river water purification facilities) and soft interventions in households, BOD concentration improved to forth worst in 2010.
Environmental regulations was established at the national level.

BOD change in 1963–2008

1. River water quality criteria
2. Pollutant discharge regulations
3. Wastewater treatment plants (WWTPs)
4. River water purification facilities
5. Dissemination of soft interventions

(Original source: MLIT)
What is “soft interventions in households”?

- Healthy Waterway: comprehensive
- Soft interventions: focusing on wastewater
- Black water and gray water
  (toilet wastewater) (other wastewater)

**Soft interventions mainly target gray water:**

- From the kitchen....... 
- From washing clothes....... 
- From bathing.......
In the kitchen......

Plastic triangle
Plastic triangle with plastic net
Solid waste trap (stainless steel)
In dining room.....

To clean your dish with paper or rag

After dining.....

What will you do after dining?

1. To wash dish with sponge and detergent
2. To leave dish on the table (someone will wash it)
3. To throw dish away every time

26 Sep 2011
Yoshiaki TSUZUKI: IRS2011
In the kitchen....

To wash your cooking apparatus only with water and sponge...no detergent.
The purposes of this presentation

• Why water quality deteriorated?
• Why water quality improved?
• Engineers may say because of technologies.
• Environmental Economics textbooks say that it is because of market failure (MF), government failure (GF) or Institutional failure (IF).

We have tried to consider the water quality changes from the Economics perspectives.
Methods and Theories with some background information
Methods

• Quantitative analysis of benefits and costs of environmental water and water resources
• Qualitative analysis on Market Failure (MF)
Figure 9 Consumer Prices Index (CPI) in Japan (prepared by the authors based on Ministry of Internal Affairs and Communications, 2011)
Population in the Yamato-gawa River basin

(Source: Ministry of Land, Infrastructure, Transportation and Tourism (MLIT))
Land use change in 1958–2005

Prepared by the authors from MLIT (http://www.mlit.go.jp/river/basic_info/jigyo_keikaku/gaiyou/seibi/pdf/yamatogawa61-5-3.pdf)

Increase of urban area
Centralised WWTPs development in 1983–2006

(Source: MLIT)

18% in 1983

76% in 2006

National average

Nara Prefecture

Yamato-gawa River basin

Osaka Prefecture

(26 Sep 2011)
Environmental regulations was established at the national level.

1978 Water uptake stoppage at Asaka WTP

The number of fisherypersons has decreased

2005 Soft interventions introduced

WWTPs development

(Original source: MLIT)
**Figure 8** Water resources in the Yamato-gawa River basin (Prepared by the authors based on Yamato-gawa River Office, 2011)

(1 m³ s⁻¹ = 31.5 GL year⁻¹)

- **Municipal water supply**
- **Industry water**
- **Agriculture water**
- **Groundwater of the Yamato-gawa river basin**
- **Yodo-gawa River**
- **Kino-kawa River**
- **Yamato-gawa River (to other river basins)**
- **From other river basins**

Water supply (m³ s⁻¹)

0 5 10

26 Sep 2011  Yoshiaki Tsuzuki
Mechanisms of pollutant discharge
Figure 2 Causes for pollutant discharge changes

Municipal wastewater

Pollutant discharge (PD) = PDC × population

- Pollutant discharge per capita (PDC) increase
- Population increase (decrease)

Industry wastewater

Pollutant discharge (PD) = PDP × production

- Pollutant discharge per production (PDP) increase
- Production increase (decrease)

Non-point sources

Pollutant discharge (PD) = PDA × area

- Pollutant discharge per area (PDA) increase
- Area increase (decrease)

a: Rice and vegetable fields area and forest area have been decreased, and urban area has been increased in 1958–2005.
Relationship between PDCs and an economic indicator in 1955–1993 (Tsuzuki, 2007)

PDC increase with economic development

PDC decrease with economic development
Figure 4 Relationships between PDC and construction cost per capita in several Asian countries (1)

The relationship was not so simple.

Large removal efficiency → Large cost

(Original source: Tsuzuki and Koottatep, 2010)
Figure 7 Causes and results of soft interventions to decrease pollutant discharge

Dissemination

Items for soft interventions

Pollutant discharge

Soft interventions

Pollutant discharge reduction

River water

- Water quality improvement
- Fishery
- Transportation
- Swimming and bathing
- Tourism
- Amenity
- Ecosystem

Coastal water
<table>
<thead>
<tr>
<th>Market failure</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>MF1. Incomplete markets</td>
<td>Water quality is a public good. There is no complete market for the public good (Coase, 1960).</td>
</tr>
<tr>
<td>MF2. Externalities</td>
<td>Water pollution is caused by pollutants discharged by someone who do not necessarily pay abatement costs.</td>
</tr>
<tr>
<td>MF3. Non-exclusion</td>
<td>Someone use too much environmental resources benefits when there is a limitation for usage of commons.</td>
</tr>
<tr>
<td>MF4. Non-rival consumption</td>
<td>Environmental goods are pure public goods when their consumption is non-rivalry and non-excludability.</td>
</tr>
<tr>
<td>MF5. Non-convexities</td>
<td>There are more than one local optimum solutions for pollution and abatement cost.</td>
</tr>
<tr>
<td>MF6. Asymmetric information</td>
<td>A stakeholder does not have enough information useful for decision making. (e.g. moral hazard, adverse selection)</td>
</tr>
<tr>
<td>MF7. Non-competitive behaviour</td>
<td>There are no competitive behaviours. (e.g. monopoly power)</td>
</tr>
</tbody>
</table>
Results and Discussion
Valuation of costs and benefits

- Water resources development from outside of the river basin
- Decrease of Inland fisherperson
- Water quality improvement
- Dissemination of soft interventions

Investments and benefits

Constant price in 2010 (JPY billion)

Yamato-gawa River System, Nara Prefecture: JPY 425 billion (= AU$ 5.31 billion)
- 16.1 billion (201 million)
- 13.1 billion (163 million)
- 30 million (0.4 million)

Yamato-gawa River System, Osaka Prefecture: JPY 500 billion

Kino-gawa River System

JPY 500 billion

= AU$ 6.25 billion

26 Sep 2011
Yoshiaki Tsuzuki

14th International Rivers Symposium
# Table 2: Target, indicator and element of MF, GF and IF of pollutant discharge by agent and motive

<table>
<thead>
<tr>
<th>Element</th>
<th>Agent</th>
<th>Motive</th>
<th>Target and indicator</th>
<th>Element of MF, GF and IF (^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDC</td>
<td>Ordinary people</td>
<td>Lifestyle improvement</td>
<td>Consumptions</td>
<td>Economic development</td>
</tr>
<tr>
<td></td>
<td>Ordinary people</td>
<td>Water quality improvement</td>
<td>WWTPs, on-site</td>
<td>External cost for pollution abatement</td>
</tr>
<tr>
<td></td>
<td>Ordinary people</td>
<td>Observance of regulations</td>
<td>WWTPs, on-site</td>
<td>External cost for pollution abatement</td>
</tr>
<tr>
<td></td>
<td>Government</td>
<td>Water quality improvement</td>
<td>WWTPs, centralised</td>
<td>Public expenses for WWTPs</td>
</tr>
<tr>
<td></td>
<td>Ordinary people</td>
<td>Family prosperity</td>
<td>Large family</td>
<td>National economic development</td>
</tr>
<tr>
<td></td>
<td>Ordinary people</td>
<td>Importance of individual life</td>
<td>Small family</td>
<td>Individual economic development</td>
</tr>
<tr>
<td></td>
<td>Ordinary people</td>
<td>Migration to urban area</td>
<td>Urban area population</td>
<td>Public incomes and expenses</td>
</tr>
<tr>
<td></td>
<td>Government</td>
<td>Growth of national economy</td>
<td>Population (increase)</td>
<td>Public incomes and expenses</td>
</tr>
<tr>
<td></td>
<td>Government</td>
<td>Alleviation of population</td>
<td>Population (decrease)</td>
<td>Public incomes and expenses</td>
</tr>
</tbody>
</table>
Some aspects of MF in Water quality deterioration in 1963–1970

• Most people did not care about the water quality as public goods (MF1)
• The society and governments have conducted measurements to alleviate the effects of discharged pollutants (MF2)
• There might be more than one equilibriums for pollutant discharges and costs for water quality improvement (MF5)
• Ordinary citizens, industries and farmers might not know that it would take so long time for water quality restoration (MF6)
Conclusions

1. In 1963, river water quality conditions were Pareto optimal.
3. There have been motivations of river water quality improvement in 1970–2010.
4. The total costs of water environment and water resources have further exceeded the valuation of water environment improvement of JPY 13.1 billion (AU$ 164 million).
Thank you for your attention.
Yamato-gawa River Drainage Area

(Original source: Physical map of the world, April 2005)
Figure 6 Conceptual figure on costs and population density of centralised and on-site WWTPs, established in the 1980’s (Modified from MLIT, 2008–2011)

Becomes necessary to think in terms of a total maintenance fee and construction fee for cost comparison

Equilibrium point

On-site....PM  Centralised.....GM

Population density

PM: Market of private purchasing
GM: Government market

Population density is a determinant factor.

Individual treatment for districts with a small number of household

Concentration treatment for districts with large numbers of households

Cost per capita

Cost per person (Construction fee + Maintenance fee)
Asymmetric information (MF6) may exist for WWTPs development.

Only Thailand data show this trend.
Figure 5 Costs (construction and maintenance) per wastewater volume are in a wide range (Japanese Yen m$^{-3}$) Japanese Fiscal Year 1995–1998 (Tsuzuki, 2011)

(Prepared by the author based on Sewage Works Project Management Research Group, 1997-2000)
Examples of wastewater treatment prefecture plan in Saga Prefecture, Japan (IDIJ, 2004)

Centralised WWTPs are in the governmental market.
Table 3 Effects of hard and soft interventions on river water quality improvement

<table>
<thead>
<tr>
<th>Motivation</th>
<th>Interventions</th>
<th>Direct effect</th>
<th>Indirect effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government investment</td>
<td>WWTPs development, centralised</td>
<td>Pollutant discharge reduction</td>
<td>River water quality improvement</td>
</tr>
<tr>
<td>Private investment</td>
<td>WWTPs development, on-site</td>
<td></td>
<td>Improvement of environmental amenity</td>
</tr>
<tr>
<td>Dissemination</td>
<td>Soft interventions in households</td>
<td></td>
<td>Fishery</td>
</tr>
<tr>
<td>Purchase of items for soft interventions</td>
<td>Soft interventions in households</td>
<td></td>
<td>Transportation</td>
</tr>
<tr>
<td>Government investment</td>
<td>River water purification facility</td>
<td>Direct river water quality</td>
<td>Swimming and bathing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tourism</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ecosystem</td>
</tr>
</tbody>
</table>
Table 4  Examples of Benefit-cost analysis of government projects: (Water environment improvement projects in the Yamato-gawa River basin (Source: Kinki Region Development Bureau of MLIT, 2009))

<table>
<thead>
<tr>
<th>Project</th>
<th>Benefit</th>
<th>Cost</th>
<th>B/C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>JPY billion in 2008</td>
<td>JPY billion in 2008</td>
<td></td>
</tr>
<tr>
<td>Water environment improvement</td>
<td>119.90</td>
<td>30.22</td>
<td>4.0</td>
</tr>
<tr>
<td>Natural environment rehabilitation</td>
<td>9.54</td>
<td>1.33</td>
<td>7.2</td>
</tr>
<tr>
<td>Promotion of river usages</td>
<td>1.85</td>
<td>0.41</td>
<td>4.5</td>
</tr>
<tr>
<td>Total</td>
<td>131.29</td>
<td>31.96</td>
<td>4.1</td>
</tr>
</tbody>
</table>

26 Sep 2011  Yoshiaki Tsuzuki  37