Waste Water treatment by Multi Soil Layering Method
Background

The use of soil for water treatment has a long history in the world.

Conventional method

- Land treatment
- Sand filter
- Septic systems (EPA)

Some limitations

- **Low permeability**
  > need large area
  > Risk of clogging

- Soil has high purification function, but is highly depends on properties of each soil type.

Increase the permeability

Regulation and enhancement of the purification functions

Multi-Soil-Layering (MSL) Method
Multi-Soil-Layering (MSL) Method

The MSL method consists of soil units arranged in a brick-like pattern surrounded by layers of zeolite or alternating particles of homogeneous sizes that allow a high hydraulic loading rate.

**Soil mixture layer** (10⁻³ cm sec⁻¹)
- andisol: high soil aggregate formation, high phosphorus adsorption ability.
- sandy soil: large particle size and high permeability
- on-site soil: low cost
- iron: phosphorus adsorption, reducing agent
- charcoal: high porosity, hydrophobic adsorbent, habitat of microorganisms
- organic matter: food for microorganisms, electron donor for denitrification

**Permeable layer** (10⁻¹ cm sec⁻¹)
- sandy soil: large particle size and high permeability
- zeolite: high NH₄⁺ adsorption ability, high CEC, high porosity
- Pumice: high porosity, low cost than zeolite
- charcoal: high porosity, hydrophobic adsorbent, habitat of microorganisms
- gravel
Conceptual diagram of Multi-Soil-Layering (MSL) Method

- Waste Water
- The soil mixture layers
- The permeable layers
- Treated Water
Treatment processes of MSL Method

Wastewater

- **PO$_4^{3-}$**
- **NH$_4^+$**

**Zeolite**
- **NH$_4^+$** adsorption

**Nitrification**
- **H$^+$**
- **NO$_3^-$**

**Denitrification**
- **H$^+$**
- **NO$_3^-$**

**Aerobic decomposition**
- **N$_2$**
- **CO$_2$**

**Anaerobic decomposition**
- **Fe**
- **Fe$^{2+}$**

**Soil mixture layer**
- **Fe(OH)$_3$**

**Metal iron**
- **Fe**

**Organic material**
- **CH$_2$O**
- **OH$^-$**
- **NO$_3^-$**

**Charcoal**
- **Hydrophobicity**

**Permeable layer**
- **Aeration**
- **PO$_4^{3-}$** adsorption

**Organic matters**
- **BOD**
- **COD**

**Anaerobic decomposition**
- **N$_2$, N$_2$O**
- **CO$_2$, CH$_4$**

**adsorption**
- **Fe(OH)$_3$**

**Aerobic**
- **Fe(OH)$_3$**

**Metal iron**
- **O$_2$**

**Organic material**
- **CH$_2$O**
- **OH$^-$**
- **NO$_3^-$**

**Charcoal**
- **Hydrophobicity**

**Permeable layer**
- **Aeration**
- **PO$_4^{3-}$** adsorption

**Anaerobic decomposition**
- **N$_2$, N$_2$O**
- **CO$_2$, CH$_4$**

**adsorption**
- **Fe(OH)$_3$**

**Aerobic**
- **Fe(OH)$_3$**

**Metal iron**
- **O$_2$**
Characteristics of the MSL method

1. High purification ability

2. High removal efficiency of N and P

3. Stable high treatment performance against fluctuation of raw water

4. Low maintenance

5. Reuse of treated water and soil

6. Harmony with the landscape
Application of the MSL Method

MSL method

- Domestic wastewater
- Toilet
- Restaurant

Sewage system, community plant

Treated water from wastewater treatment plant

removed:
N, P, BOD, COD, etc.

Treated Water

Polluted environmental water

COD

P
Application case

Park

Small scale community
# Performance of the MSL Method

## Loading rate

- **BOD, T-N, T-P removal**
  - The standard is $100\text{L m}^{-2}\text{day}^{-1}$.
- **BOD removal only**
  - It can be increased up to $4000\text{L m}^{-2}\text{day}^{-1}$

## Experimental results (in Shimane University)

<table>
<thead>
<tr>
<th>type of water (loading rate)</th>
<th>raw water (mg/l)</th>
<th>treated water (mg/l)</th>
<th>removal rate(%)</th>
</tr>
</thead>
</table>
| **I**
  - river, lake,
treated water from wastewater treatment plant
  - (200-5000 L M $^{-3}$ day $^{-1}$)
| raw water (mg/l) | 25 | 2.7 | 12 |
| treated water (mg/l) | 5 | 1.7 | 4 |
| removal rate(%) | 77 | 44 | 52 |
| **II**
  - domestic and toilet wastewater
  - (200-2000 L M $^{-3}$ day $^{-1}$)
| raw water (mg/l) | 190 | 6.5 | 58 |
| treated water (mg/l) | 16 | 1.7 | 30 |
| removal rate(%) | 91 | 75 | 48 |
| **III**
  - livestock wastewater
  - high polluted water
  - (30-300 L M $^{-3}$ day $^{-1}$)
| raw water (mg/l) | 1400 | 40 | 240 |
| treated water (mg/l) | 47 | 5.4 | 92 |
| removal rate(%) | 96 | 88 | 61 |
### Results of practical use

<table>
<thead>
<tr>
<th>type of water (loading rate)</th>
<th>BOD</th>
<th>T-P</th>
<th>T-N</th>
</tr>
</thead>
<tbody>
<tr>
<td>[park]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a public latrine</td>
<td>5.4</td>
<td>4.46</td>
<td>39.4</td>
</tr>
<tr>
<td>(100 L M⁻³ day⁻¹)</td>
<td>treated water (mg/l)</td>
<td>0.7</td>
<td>0.04</td>
</tr>
<tr>
<td>removal rate(%)</td>
<td>81.7</td>
<td>99.1</td>
<td>60.7</td>
</tr>
<tr>
<td>[estate, office]</td>
<td>44.1</td>
<td>4.72</td>
<td>45.8</td>
</tr>
<tr>
<td>a cooperative society office in Osaka</td>
<td>raw water (mg/l)</td>
<td>treated water (mg/l)</td>
<td>8.5</td>
</tr>
<tr>
<td>(30 L M⁻³ day⁻¹)</td>
<td>removal rate(%)</td>
<td>80.7</td>
<td>71.4</td>
</tr>
<tr>
<td>[house]</td>
<td>53.2</td>
<td>7.82</td>
<td>64.8</td>
</tr>
<tr>
<td>advanced treatment of domestic wastewater</td>
<td>raw water (mg/l)</td>
<td>treated water (mg/l)</td>
<td>4.8</td>
</tr>
<tr>
<td>(100 L M⁻³ day⁻¹)</td>
<td>removal rate(%)</td>
<td>90.9</td>
<td>89.6</td>
</tr>
<tr>
<td>[river]</td>
<td>15.7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>direct river treatment system in Kumazoe River</td>
<td>raw water (mg/l)</td>
<td>treated water (mg/l)</td>
<td>1.6</td>
</tr>
<tr>
<td>(4000 L M⁻³ day⁻¹)</td>
<td>removal rate(%)</td>
<td>90</td>
<td>-</td>
</tr>
</tbody>
</table>
Domestic wastewater treatment

Plan of treatment quantity: 1m³/day

Actual loading rate: 100~250L/m²/day
Evaluation of system performance during the 10 years operation

Change of BOD, T-P, T-N concentration and removal percentage of treated water
Application case:
Treatment of Polluted River Water by the MSL Method
Kumazoe River purification project

Location of Kumazoe River and situation of the watershed
Kumazoe River basin
The general situation of Kumazoe River

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>The catchment area</strong></td>
<td>2.5km² (the urban area: about 80%)</td>
</tr>
<tr>
<td><strong>Length of river channel</strong></td>
<td>1.2km</td>
</tr>
</tbody>
</table>
| **River flow**               | average of winter: 7000m³ day⁻¹  
                             |   average of summer: 28000 m³ day⁻¹ |
| **Quality of the river water**| average BOD concentration of  winter 55mg L⁻¹  
                             |   average BOD concentration of summer 9 mg L⁻¹ |
The contents of the project

The design parameters of the MSL method
Targeted quantity of the river water: 7000m$^3$ day$^{-1}$ (the target is mean river flow of winter)
Targeted quality of the river water: BOD 15.7 mg L$^{-1}$ (on the average)
   BOD 50 mg L$^{-1}$ (on the maximum)
Targeted quality of the treated water: less than BOD 1.6mg L$^{-1}$
   (BOD removal rate: 90%)

The scale of the MSL method
Site area: the MSL method  1750m$^2$
   total 6 series: 5 series of 6 series are always alternate operations.
   : pre-treatment system for SS removal (a contact oxidation system)

The construction details of the MSL method
The construction period: September,2002 ~ March,2005 (start: April,2005~)
The cost of construction: 7.7 hundred million yen
110 thousand yen  per 1m$^3$ day$^{-1}$ of the water quantity
A plan for Kumazoe River purification project

Pre-treatment System

MSL Method

Kumazoe River

Sluice

Administration building

Onga River
Kumazoe River purification facilities (the MSL method)
The demonstration experiment of pilot scale on the site for Kumazoe River purification project

The scale of the system

<table>
<thead>
<tr>
<th></th>
<th>Water quantity for treatment</th>
<th>(Loading rate)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>144m$^3$day$^{-1}$ (4m$^3$m$^{-2}$day$^{-1}$)</td>
<td></td>
</tr>
<tr>
<td>Pre-treatment system</td>
<td>72m$^3$day$^{-1}$ $\times$ 2</td>
<td></td>
</tr>
<tr>
<td>The MSL method</td>
<td>48m$^3$day$^{-1}$ $\times$ 3</td>
<td></td>
</tr>
</tbody>
</table>
A performance of demonstration experiment

Seasonal change of BOD concentration in the demonstration experiment

source: survey by Ministry of Land, Infrastructure and Transport
Dairy change of BOD concentration in the demonstration experiment

source: survey by Ministry of Land, Infrastructure and Transport
# The comparison of performance and cost

<table>
<thead>
<tr>
<th></th>
<th>MSL system</th>
<th>contact oxidation system by gravel with aeration</th>
<th>contact oxidation system by gravel and various types of plastic modules with aeration</th>
<th>advanced contact oxidation system by gravel with aeration</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD of influent water (mgL(^{-1}))</td>
<td>55</td>
<td>55</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>BOD of effluent water (mgL(^{-1}))</td>
<td>5</td>
<td>14</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>site area (m(^2))</td>
<td>2,300</td>
<td>2,400</td>
<td>1,200</td>
<td>1,000</td>
</tr>
<tr>
<td>construction cost (million yen)</td>
<td>440</td>
<td>512</td>
<td>1,031</td>
<td>440</td>
</tr>
<tr>
<td>maintenance cost (thousand yen)</td>
<td>6,000</td>
<td>6,600</td>
<td>18,000</td>
<td>6,000</td>
</tr>
</tbody>
</table>

Source: The above construction cost are used as an example, and so are difficult to the real cost.
The construction processes of the MSL method

In making of the soil mixture layers, a nonwoven fabric was laid in the plastic cage and the mixed soil was filled up in it.

These blocks were laid like left picture.

The void spaces (permeable layers) between each block and block sides were filled with pumice.

The inlet pipe was installed at the top of the system.

Soil is covered on the surface of the system.
reference data
Structure of Multi Soil Layering Method

Perspective figure
Cross Section

- Masa soil
- Plastic net
- Gravel 40mm
- Porous pipe VU75mm

- Ceramic cups for collection of soil solution
- Drainage pipe
- Aeration pipe
- Soil, Jutepellet, Iron Mixture
- Jute net
- Zeolite 1-3mm
- Plastic net
- Gravel 40mm
- Vinyl sheet
Evaluation of system performance during the 10 years operation

Daily fluctuation of waste and treated water (1991/2/13-14)
Evaluation of system performance during the 10 years operation.

Daily fluctuation of waste and treated water (1999/12/22)

(left axis) WW BOD, TW BOD, WW PO₄-P, TW PO₄-P

(right axis) WW T-N, TW T-N

(mg/L⁻¹)
MSL structure and type of water treatment

Heavily polluted water
Low loading rate

Toilet, Restaurant ww treatment

Moderately polluted water
High loading rate

Advanced treatment of sewage or domestic ww

Less polluted water
High loading rate

Direct treatment of polluted river water

Unit size is decided depending on the degree of treatment needed.
Prevention mechanisms of clogging and shortcut in the MSL method

Lack of uniformity

(1) Water flow in soil
(2) Water flow in the MSL method
(3) Difference of water flows by various materials

Clogging

(a) Shortcut
(b) Clogging
(c) Prevention effect by MSL method

Improvement of contact efficiency and filtration function
Improvement of $\text{PO}_4\text{-P}$, COD, SS removal

(1) Water flow in soil
(2) Water flow in the MSL method
(3) Difference of water flows by various materials