The 3rd International conference on Sustainable Remediation

Sustainable Remediation Progress in Taiwan: Framework, Tools and Case Studies

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The 3rd Sustainable Remediation Conference – Ferrara (Italy), September 17-19
Outline

• GSR development road map
• GSR Framework
• GSR Tools
• Case studies
• Challenges for promoting GSR
The concepts of green remediation were introduced and initiated by Taiwan Environmental Protection Administration (TEPA).

- Visit of the London Olympic Site
- Paper review of GR

- GR Sites – pilot study: greenhouse gases (GHGs) evaluation & BMPs application

- Framework for GSR

- Contaminated sites GSR certification system (draft)

- 3 full-scale case studies

- Organized 2012 Taiwan Sustainable Remediation Forum
- Establishment of SuRF-Taiwan
- Conduct GSR pilot study
- Participation in SURF 20, SURF 21

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GSR Framework

- Incorporate GSR into the life-cycle of site management
- Adopt GSR in the early stage of site management

Graphical representation:

1. **Site Investigation**
   - Environmental footprint assessment, local resident questionnaire
   - Implement BMPs

2. **Remedy selection and design**
   - GSR semi-quantitative decision support tool
     - Comparison of Alternatives
     - Environmental, social, economic evaluation tools
     - Selecting the most sustainable remedy

3. **Remedy system construction**

4. **Remedy system O&M**

5. **Site closure**

   - BMPs planning
     - Environmental – conduct environmental footprint assessment, identify potential emission “hot spots”, reduce footprint
     - Economic – economic efficiency
     - Social – Human health risk, stakeholder involvement, information publicity and mitigate disturbance
GSR Framework

Key issues
- Remedy selection

BMPs planning and implementation

Site Investigation

Remedy selection and design

Remedy system construction

Remedy system O&M

Site closure
GSR tools

- **GSR Semi-quantitative decision support tool**
  - Compare the environmental, social and economic effects of different remedies to select the one which most fits the sustainable requirements

- **Quantitative tool**
  - Environmental: environmental footprint assessment
  - Social: local resident questionnaire, health risk assessment
  - Economic: cost / benefit and impact assessment

- **Qualitative tool**
  - Best Management Practices screening list
GSR Semi-quantitative decision support tool

- **Initial screening**
  - Time, technology, financial feasibility

- **Decision support tool**
  - Selection of assessment metrics
  - Define weighting factors
    - Invite stakeholder
  - Scoring system
    - Systematic scoring principle
  - Total Score
    - Select the remedy with highest overall score
Footprint analysis

- **Inventory sheet**
  - Labor/equipment/material transportation, equipment operation, solid/liquid waste treatment, lab analysis, water usage

- **Output**
  - \( \text{CO}_2, \text{NO}_x, \text{SO}_x, \text{PM}_{10}, \text{MJ} \)
  - Hot spot Identification
Social & Economic Aspect

- **Social**
  - Communication Questionnaire
    - Negative impacts (noise, dust, odor...etc)
  - Human health risk assessment
    - Baseline risk & risk due to remediation of local residents and remediation workers
    - Occupational safety during remediation

- **Tiered Economic cost-benefit prediction model**
  - Land value influence prediction
  - Economic Benefit Prediction Model
    - Based on I/O Model
      - Land value influence prediction
      - Effect of increasing employment
      - Effect of increasing related industrial income
      - Effect of increasing national income
Case study 1

- Site background
  - Military port for ship maintenance with multifacotories and outdoor fuel storage areas
  - Contaminated media: Soil
  - Contaminants: TPH and heavy metals

- Stakeholder identification
  - Navy, City Environmental Protection Bureau

- GSR scope and goal definition
  - Remedy selection through GSR assessment

Diagram:
- Current status analysis
- Main stakeholders communication
- Remedial technology initial screening
- Alternative comparison
- Site background overview
  - Stakeholder identification
  - GSR scope and goal definition
  - Environmental footprint assessment
  - Social impact assessment
  - Economic impact assessment
Case study 1

- Remedy initial screening
  - After considering the need of stakeholders, excavation and soil replacement and soil washing were considered suitable for site

<table>
<thead>
<tr>
<th>alternatives</th>
<th>TPH</th>
<th>Heavy metal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>excavation and treatment</td>
<td>excavation and soil replacement</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>excavation and treatment</td>
<td>Soil washing</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>Soil washing</td>
<td>excavation and soil replacement</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>Soil washing</td>
<td>Soil washing</td>
</tr>
</tbody>
</table>
Case study 1

- **Alternative comparison**
  - Environmental footprint differences
  - Identify high contribution activities
Case study 1

- **Human health risk assessment**
  - Area specific (area A, area C, area D)
  - Area B is excluded due to lack of data
  - Assumption: soldiers do not have cross area activities, remedial worker work in multi-areas

- **Economic impact assessment**

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Project cost</th>
<th>Change in the land value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3166</td>
<td>5000</td>
</tr>
<tr>
<td>2</td>
<td>10600</td>
<td>11100</td>
</tr>
<tr>
<td>3</td>
<td>4466</td>
<td>4933</td>
</tr>
<tr>
<td>4</td>
<td>12066</td>
<td>12533</td>
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</table>

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Industries output effect</th>
<th>Value added effect</th>
<th>Job effect (person)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5000</td>
<td>3000</td>
<td>128</td>
</tr>
<tr>
<td>2</td>
<td>17600</td>
<td>10600</td>
<td>450</td>
</tr>
<tr>
<td>3</td>
<td>7400</td>
<td>4466</td>
<td>189</td>
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<tr>
<td>4</td>
<td>20000</td>
<td>12066</td>
<td>512</td>
</tr>
</tbody>
</table>

(Thousand $US)
Case study 2

- **Site background**
  - Military base
  - Contaminated media: groundwater
  - Contaminant: Trichloroethylene
  - Current remediation: Enhanced bioremediation

- **Stakeholder identification**
  - Army, County Environmental Protection Bureau

- **GSR scope and goal definition**
  - Footprint assessment
  - Human health risk for soldiers and remedial workers
  - BMPs planning

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**Information Flow Diagram**

- Site background overview
- Stakeholder identification
- GSR scope and goal definition
- Current status analysis
- Main stakeholders communication
- Environmental footprint assessment
- Human health risk assessment
- Remedy system optimization
- BMPs Planning
### YA-MW2

<table>
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<tr>
<th>Groundwater level (m)</th>
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<tr>
<td>Contaminant</td>
<td>Concentration (mg/L)</td>
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<tr>
<td>cis-1,2-dichloethylene</td>
<td>0.0958</td>
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<tr>
<td>TCE</td>
<td>0.00489</td>
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### YA-MW1

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<tr>
<th>Groundwater level (m)</th>
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<tr>
<td>Contaminant</td>
<td>Concentration (mg/kg)</td>
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<tr>
<td>cis-1,2-dichloethylene</td>
<td>0.00421</td>
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<tr>
<td>TCE</td>
<td><strong>0.286</strong></td>
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</table>
Case study 2

**kg CO₂**

- Construction: 0
- O&M: 80,000
- Periodic sampling: 40,000

**Kg Nox**

- Construction: 50
- O&M: 300
- Periodic sampling: 300

**O&M**

- Kg CO₂: 100%
- Kg Nox: 90%
- Kg SO₂: 80%
- Kg PM10: 70%
- Energy (MJ/kg)

**Periodic sampling**

- Kg CO₂: 0%
- Kg Nox: 0%
- Kg SO₂: 0%
- Kg PM10: 0%
- Energy (MJ/kg)

Legend:
- Material
- Equipment
- Transportation
- Solid waste
- Water usage and waste water treatment
- Lab analysis
Case study 2

- Economic cost-benefit prediction model

<table>
<thead>
<tr>
<th>Categories of indicators</th>
<th>Impact (thousand $US)</th>
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</thead>
<tbody>
<tr>
<td>Change in the land value</td>
<td>976</td>
</tr>
<tr>
<td>Project cost</td>
<td></td>
</tr>
<tr>
<td>Initial activities cost</td>
<td>433</td>
</tr>
<tr>
<td>Annual O &amp; M cost</td>
<td>117</td>
</tr>
<tr>
<td>Periodic activities cost</td>
<td>260</td>
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<tr>
<td>Economy impacts</td>
<td></td>
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<tr>
<td>Industries output effect</td>
<td>1,467</td>
</tr>
<tr>
<td>Value added effect</td>
<td>873</td>
</tr>
<tr>
<td>Job effect</td>
<td>23 (person)</td>
</tr>
</tbody>
</table>

- Human health risk assessment
  - Carcinogenic risks:
    - Soldiers: $4.13 \times 10^{-11}$
    - Remedial workers: $1.00 \times 10^{-14}$
  - Non-carcinogenic risks:
    - Soldiers: $1.55 \times 10^3$
    - Remedial workers: $1.99 \times 10^{-1}$
## Case study 2

### BMPs Planning

<table>
<thead>
<tr>
<th>Category</th>
<th>BMPs</th>
<th>GSR principle</th>
<th>Documentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power and fuel</td>
<td>Use pulsed rather than continuous injections when delivering amendments</td>
<td>Energy conservation increase energy efficiency</td>
<td>Operation record</td>
</tr>
<tr>
<td></td>
<td>Consider using gravity flow to deliver amendments</td>
<td>Energy conservation</td>
<td></td>
</tr>
</tbody>
</table>

- **Power and fuel**
  - Use pulsed rather than continuous injections when delivering amendments
  - Consider using gravity flow to deliver amendments

- **Conversion factor for Laboratory is based on cost**
  - **Suggestion**
    - Need detailed footprint assessment to optimize the accuracy for lab analysis
Lesson learned and challenges

• TEPA Top-down approach
  – Clear rule
    • Core element, principles, systematic approach
  – Need for a tiered GSR assessment
    • When to adopt the GSR decision support tool?
    • Different criteria for different type of sites
      – Ex: sites in urban area/ ecological impact
        private sites / economic benefit prediction
        farm land / soil impact
  – Stakeholder involvement
    • Weighting, Number of people to be involved
  – BMPs planning based on quantitative assessment? Or simple BMPs planning?
    • Site area? Site concentration? Site location?
Thank you for your attention

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