Introduction of KOMIR (Korea Mine Rehabilitation and mineral Resources Corporation), Sanha E&C, and their experiences for mine closure consulting and techniques

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https://scholar.google.com.sg/citations?user=HhsxdJwAAAAJ&hl=en

https://www.jentl.net/

KOMIR Sanha ENC

Career, publication and projects

1999.09 – 2003.10	PhD	Univ. Wisconsin-Madison
2016.03 – 2016.03	Associate Prof.	Kwangwoon University
2012.10 – 2016.03	Professor	University Malaya (Malaysia)
2014.09 – 2017.08	Associate Editor	Chemosphere (Elsevier)
2006.12 – 2012.10	Part Leader	Korea Mine Reclamation Corp.
2006.01 – 2006.12	Postdoc Fellow	Penn State University, USA
2003.10 – 2005.12	Postdoc Fellow	Univ. Wisconsin-Madison, USA
1999.09 – 2003.10	Research Assis.	Univ. Wisconsin-Madison, USA
1998.05 – 1999.06	Researcher	Korea Institute of Science and Tech.

- Research field: Development of economical nano-structured adsorbents and catalysts, for treating organic and inorganic toxic pollutants.
- **Publication: > 150 peer reviewed articles on the arsenic and heavy metals remediation, mine reclamation, and advanced oxidation process (AOP).** WORLD'S TOP 2% SCIENTISTS IDENTIFIED BY STANFORD UNIVERSITY (2020, 2021, 2022 Environmental science field)
- **Oversea projects experience: mine reclamation and closure plan, environmental nanotechnologies, geochemistry, and process water treatments**.

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Korea Mine Rehabilitation and Mineral Resources Corp.
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01

Introduction of KOMIR

General status of KOMIR

Objectives of establishment

- Revitalize the mining area economy by managing mine damage and supporting the mineral resources industry
- Contribute to the development of the national economy by promoting the stable supply and demand of mineral resources

Establishment date

- 2021. 9. 10

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mireco Mine Reclamation Corp. + KORES 한국광물자원공사 KOREA RESOURCES CORPORATION

Damage prevention and recovery (1987~2021)

Mineral resource development (1967~ 2021)

General status of KOMIR

Main tasks

- **Investigation/technology development and mine reclamation businesses to prevent and restore environmental damages caused by mine development**
- **To revitalize the economy of the abandoned mine area** through abandoned mine area promotion projects
- **International cooperation projects** for overseas expansion of mine reclamation projects
- **National technical qualification examination projects** and **specialized mining education** for mining manpower training
- To stabilize coal price and establish coal/briquette distribution order by coal and briquette industry support project
- Technology and fund support and technology development necessary to secure domestic and foreign mineral resources
- Mineral stockpiling project to strengthen national resource security function

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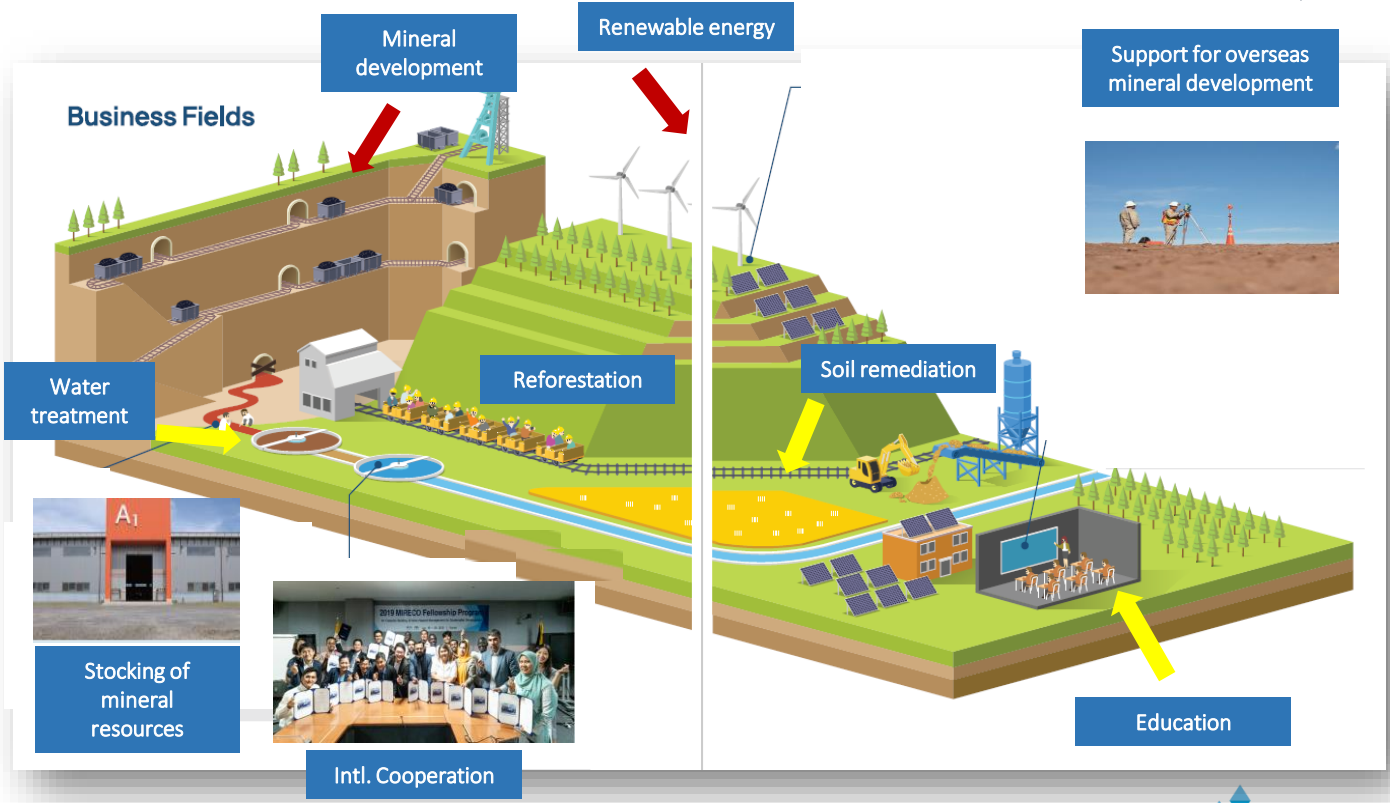
General status of KOMIR

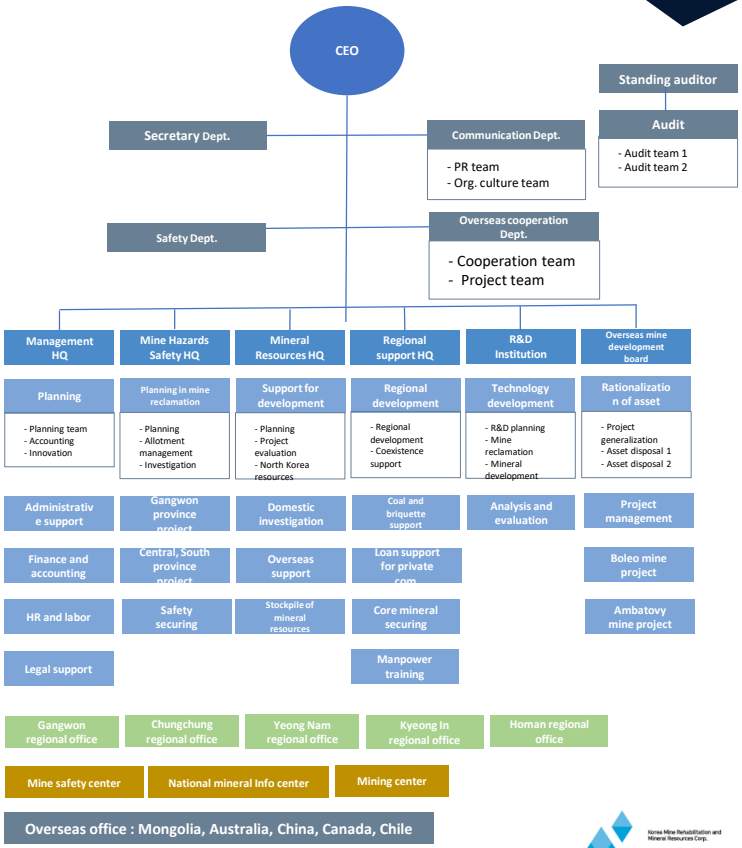
Main tasks



General status of KOMIR

Organization

4 Headquarters, 29 Offices, 5 branches, 3 centers, 5 overseas offices



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Main tasks of KOMIR

Mine hazards prevention and recovery (1)

(Mine damage) Investigation of mine damages every 5 years

- Mine damages confirmed at 7,181 locations in 3,300 mines out of 5,800 operating/ abandoned mines

(Procedure of reclamation) "Act on the prevention and recovery of mine damage Article 7"

Reclamation basic plan (5 yr) ➔ Reclamation action plan ➔ Reclamation business plan ➔ Reclamation project ➔ Management of reclamation projects

(Reclamation project) Investigation of mine damage factors, design, restoration works and follow-up management

- As the end of 2021, a total 1566 locations (21.8%) projects completed

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Main tasks of KOMIR

Mine hazards prevention and recovery (2)

(Water treatment)

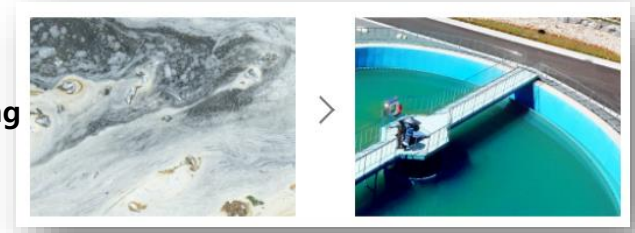
- Damage prevention caused by mine drainage
- Application of water treatment method according to site and water quality characteristics
- Maintenance and management of water treatment facilities (59)

(Soil remediation)

- Creating safe agricultural environmental around mines
- Farmland function maintenance based on economic feasibility
- Compensation system during restoration project

(Tailing release prevention)

- Pollutants removal, stabilization, detoxification
- Maintenance and management of tailing storage facilities (59)



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Main tasks of KOMIR

Mine hazards prevention and recovery (3)

(Forest and land restoration)

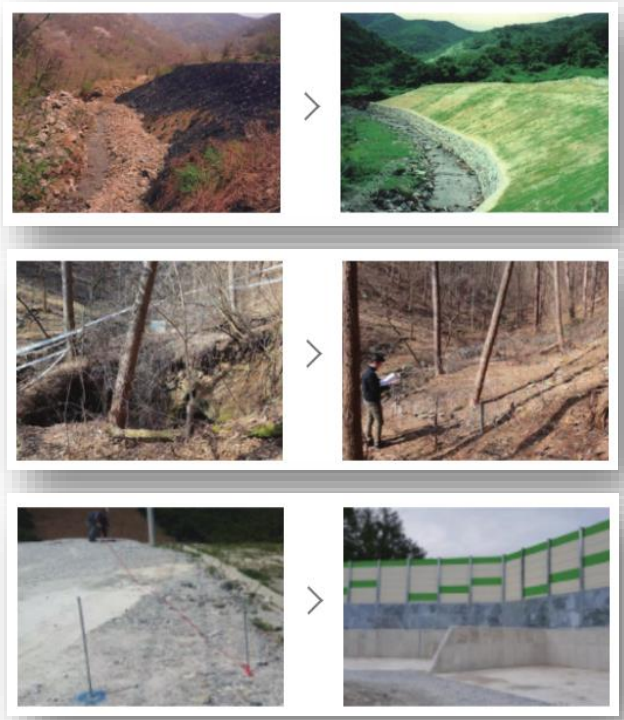
- Restoration of damaged forests
- Planting suitable tree species by region
- Measures to prevent waste rock loss

(Prevention and restoration of ground subsidence)

- Ground stability investigation, ground reinforcement and restoration

(Noise, Vibration, Dust Prevention)

- Installation support for soundproof walls, dust collection facilities, and wheel washing facilities



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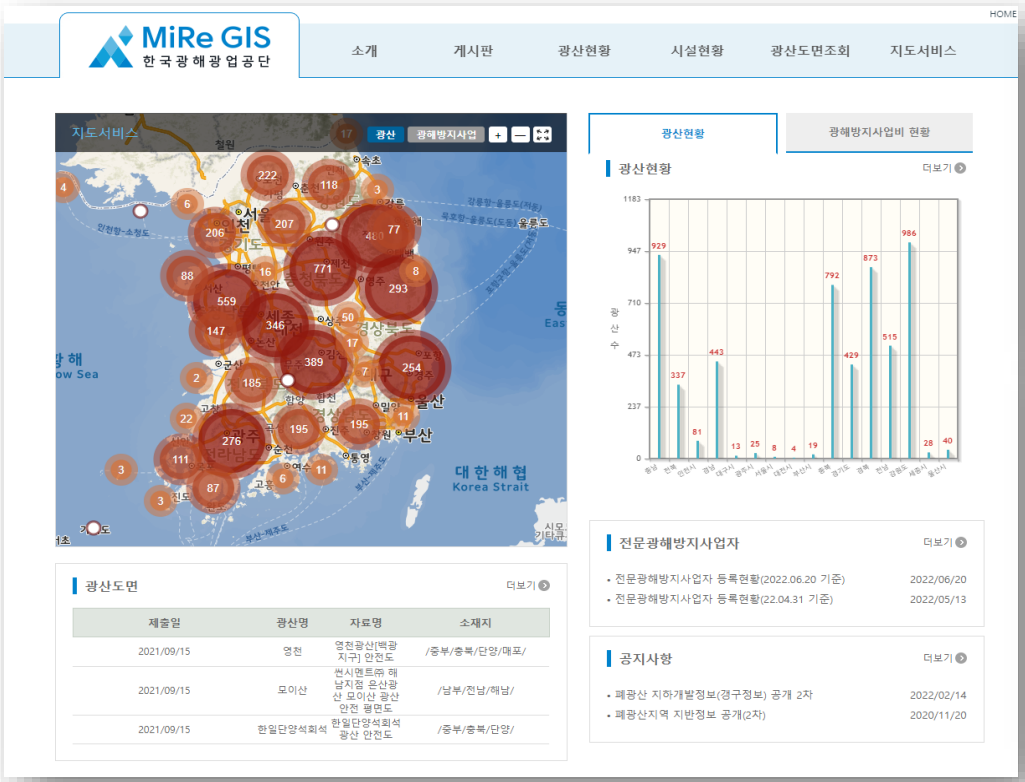
Main tasks of KOMIR

Mine damage information integrated management system (MiRe GIS)



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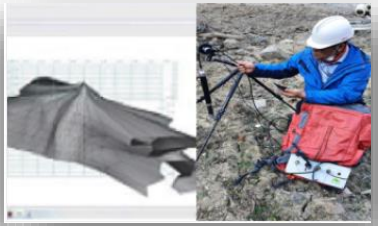
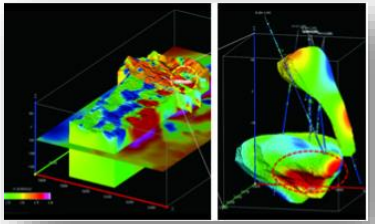
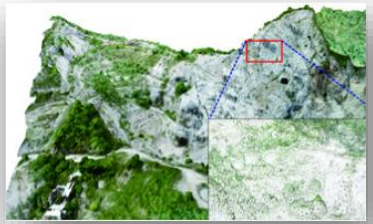
Main tasks of KOMIR

Research and development of core technology

• (Prevention of mine damage) Development and application of on-site technology suitable for mine damage site


• (Resources development) Technology for resource development and improving added value of minerals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Main tasks of KOMIR

National technical qualification examination project and specialized mining education

• National technical qualification examination project) National technical qualification certification for 7 categories of mining resources field (mine damage, resources)



• (Specialized mining education) Specialized education and training for mining resources field and safety education for mine workers




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Main tasks of KOMIR

Domestic resource development support project to private sector (1)

- (Exploration support) Exploration support project to secure stable mineral resources supply

  - Detailed exploration, Korea Mineral Resources Geographic Information System (KMRGIS) establishment , National Mineral Info Center operation, etc.




- (Development support) Support project to improve resources development productivity and added value

  - Prospecting and excavation of metal minerals, modernization development, smart mining



KOMIR

Main tasks of KOMIR

Korea Mineral Resources Geographical Information System (KMRGIS)

KOMIR

Main tasks of KOMIR

Domestic resource development support project to private sector (2)

• (Loan support) Loan support for mining right holders, quarry workers, mineral processors

- Mining fund loan, mineral products processing fund loan, stone and aggregate industry fund loan



• (Mine safety management) Safety securing to prevent accidents and minimize damages in mines

- Mine safety facilities and technology support, mine safety rule review, mine safety education, mine safety promotion


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Main tasks of KOMIR

Oversea resource development support project to private sector

• (Exploration support) Conducting and supporting exploration cost at initial stage of oversea resources development

• (Technical support) Providing technical support to private oversea resource development by field experts

- (Matching service) Providing investment info about oversea promising projects and supporting exploration technologies

- (Incubating exploration) Transferring to private sector the promising businesses discovered and explored by KOMIR

- (Technology consulting) Providing combined technical consulting with KOMIR's mine valuation capabilities

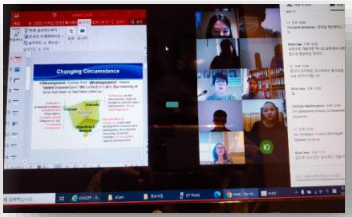
KOMIR

International cooperation of KOMIR

Current status of international cooperation projects (1)

• International cooperation projects with major mining countries to contribute to sustainable worldwide mining development

- (International exchange and cooperation business)
  - · Signed 69 business agreements with 19 countries including MOU (28 cases)
  - · Held 133 times in 39 countries, including invitational training and local seminars (about 4,130 people)
- (ODA, consulting, etc) Total 124 cases, received 35.7 billion KRW project order
  - · 88 cases in the public sector including ODA, and conducted 28.3 billion KRW projects
  - · Consulting 36 cases for overseas institutions and small and medium sized enterprises (SMEs), Conducted 7.4 billion KRW project
- (Support for Overseas expansion of SMEs) Global win-win cooperation network operation (29 companies participated)



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02

Mine Water Treatment

Deleterious effects of AMD

- Water (groundwater) contamination and restriction for water use
- Breakout of eco-system and harmful effects for human health
- Sight damages by sediments
- Corrosion for facilities and equipments
- Spread-out of bad images and cause of reclamation expenses

Sulfur Containing Minerals

FeS_2	-	pyrite	MoS_2	-	molybdenite
FeS_2	-	marcasite	NiS	-	millerite
Fe_xS_x	-	pyrrhotite	PbS	-	galena
Cu_2S	-	chalcocite	ZnS	-	sphalerite
CuS	-	covellite	FeAsS	-	arsenopyrite
$CuFeS_2$	-	chalcopyrite			







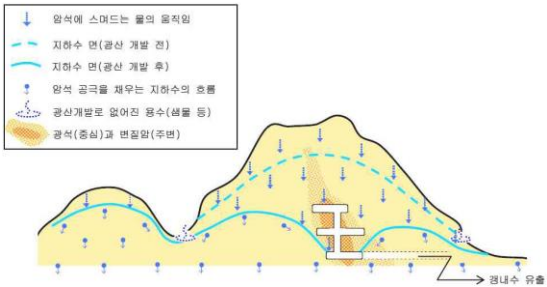


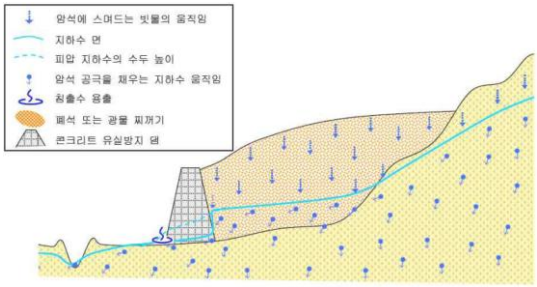


Classification of Mine Water

Form of discharge

- Mine drainage : underground, open pit
- Leachate : tailings, waste rock dump





Ore deposit

- Coal mine water
- Metal mine water
- Non- metal mine water

Formation of AMD

Pyrite

Marcasite

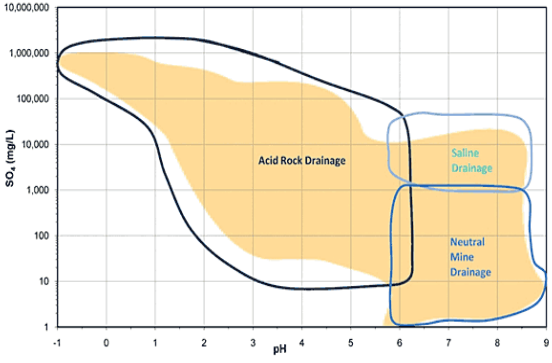
- **Prevention of water and air will stop the weathering of pyrite and marcasite**

$$FeS_2 + 3.5O_2 + H_2O \rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+$$

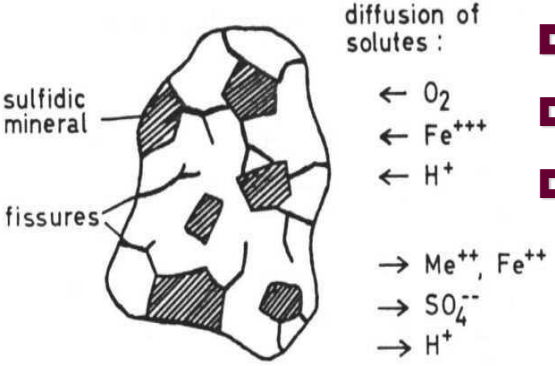
$$Fe^{2+} + 0.25O_2 + H^+ \rightarrow Fe^{3+} + 0.5H_2O$$

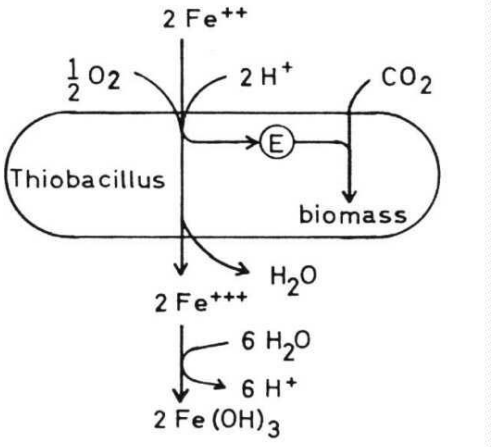
$$Fe^{3+} + 3H_2O \rightarrow Fe(OH)_3\downarrow + 3H^+$$

$$FeS_2 + 14Fe^{3+} + 8H_2O \rightarrow 15Fe^{2+} + 2SO_4^{2-} + 16H^+$$

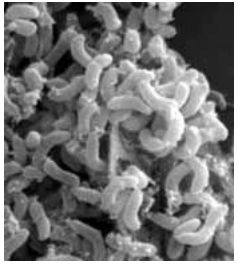


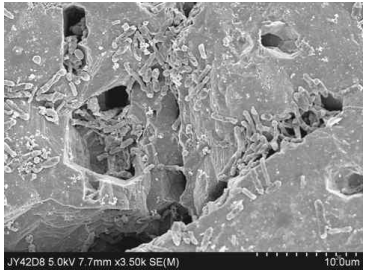
Iron Oxidizing Bacteria (IOB, Thiobacillus)

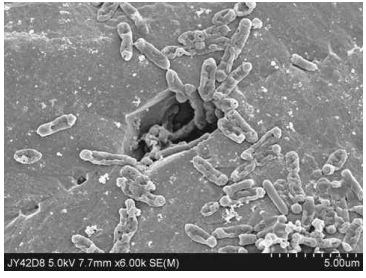




- AMD maker, Aerobic bacteria
- Gram-negative, rod-shaped
- Acidophilic : requiring pH 1.5~3.5







조강희 외, 2010

Assessment Procedure of Mine Water

On site and document survey

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Monitoring and analysis

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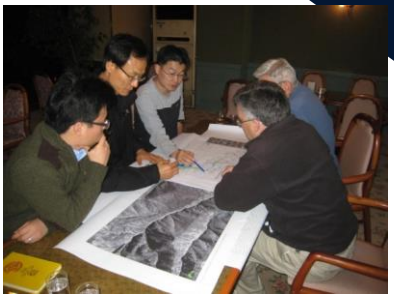
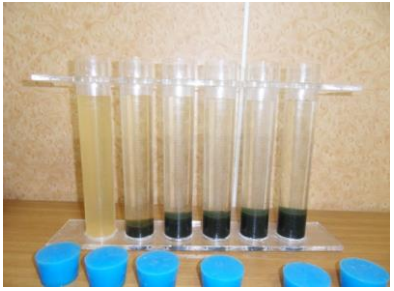
Characterization of mine water

↓

Control or treatment





Survey of Mine Water

On-the-spot and document survey

- geology, topography, hydro-geology, water system,
- related regulation, treatment target, weather, precipitation etc.

Analytical variables to confirm characteristics of mine water

Site	Variables	unit	Filtering	Reasons for inclusion
On-site	Temp., Flow rate	°C, m^3/d	X	property and design factor
	pH, EC, ORP, DO	μS/cm, mV, mg/L	X	property of water quality
	Fe^{2+}, Alkalinity	mg/L($CaCO_3$)	X	design factor
Lab (ICP, AA, IC)	Na, Ca, Mg, K	mg/L	O, X	mass balance for quality control
	Fe, Al, Mn, Acidity	mg/L($CaCO_3$)	O, X	coal mine contaminants
	As, Cu, Zn, Ni, Cd	mg/L	O, X	metal mine contaminants
	Pb, Hg, Co, U, etc.	mg/L	O, X	some mine contaminants
	F, Cl, NO_2, SO^4,	mg/L	O, X	mass balance for quality control

Geochemical characteristics depending on the variables

Temperature

Mine Water

affected by underground pit water

affected by surface water

stationary

changeable

pH, ORP

pH > 6

6>pH >8

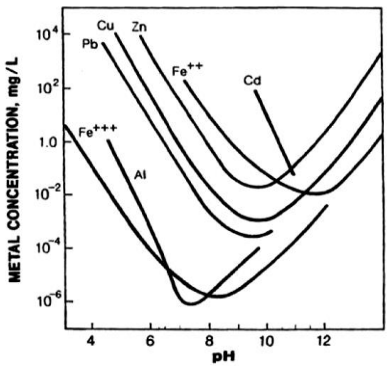
pH < 8

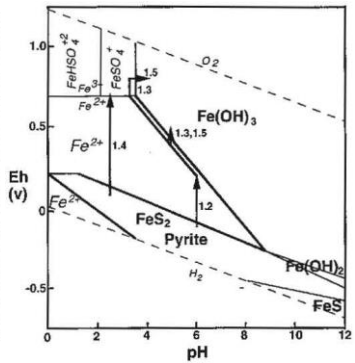
ORP > 0mV

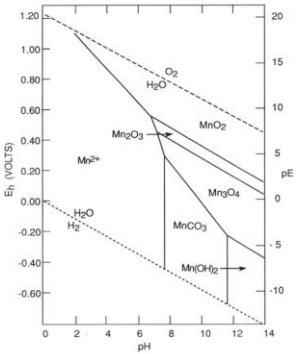
ORP < 0mV

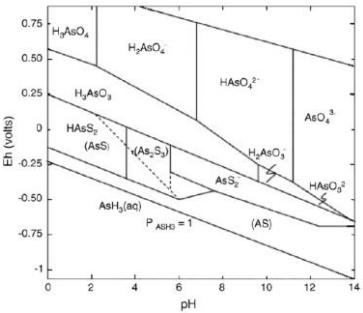
Mobility Species

Chemical species		pH,ORP
Fe^{2+}	Fe^{3+}	?
Mn^{2+}	Mn^{4+}	?
As^{3+}	As^{5+}	?
Cr^{3+}	Cr^{6+}	?







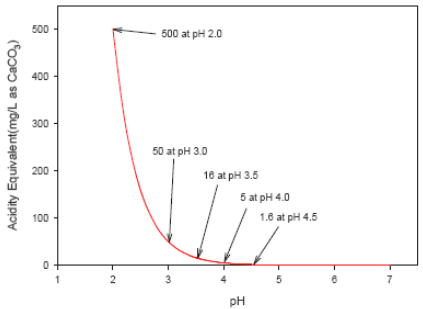


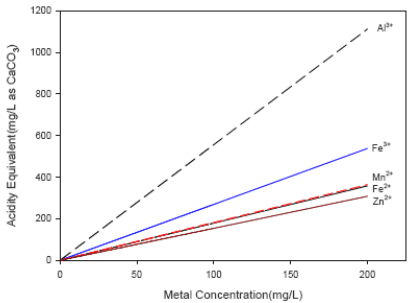
Geochemical characteristics depending on the variables

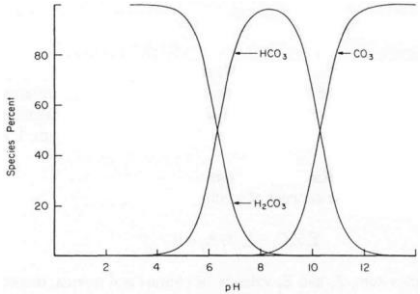
Acidity and Alkalinity

Acidity

$$\text{total acidity} = [H^+] + [HCO_3^-]_{(\text{mineral acidity})}$$
$$= 50{,}045 \times 10^{-\text{pH}} + 1.79C_{Fe^{2+}} + 2.69C_{Fe^{3+}} + 5.56C_{Al^{3+}} + 1.82C_{Mn^{2+}} + 1.54C_{Zn^{2+}}$$







Alkalinity

$$\text{Alkalinity} = [HCO_3^-] - [H^+] \qquad HCO_3^- + H^+ \rightarrow H_2O + CO_2$$

$$\text{Net acidity (mg/L } CaCO_3) = -\text{Net alkalinity}$$
$$= \text{Acidity}_{\text{calculated,Eq.(14)}} - \text{Alkalinity.}$$

$$\text{Net alkalinity (mg/L } CaCO_3)$$
$$= \text{Alkalinity}_{\text{measured}} - \text{Acidity}_{\text{calculated,Eq.}}$$

Categorization of Mine Water

Geochemical properties of mine water

Type	pH and mineral acidity	Ore
A	Acidic / Fe and base metal ↑	Cu, Pb, Zn, Au, Ag etc.
B	Acidic / Fe and As ↑	Sulfide mineral, limonite, Au
C	Slightly acidic / Mn and base metal ↑	Pb, Zn, Mn
D	Neutral / As↑	Au, As
E	Neutral / Cd and Zn ↑	Pb, Zn, Sn, W etc.
F	Slightly acidic / Fe, Al and Mn ↑	Coal

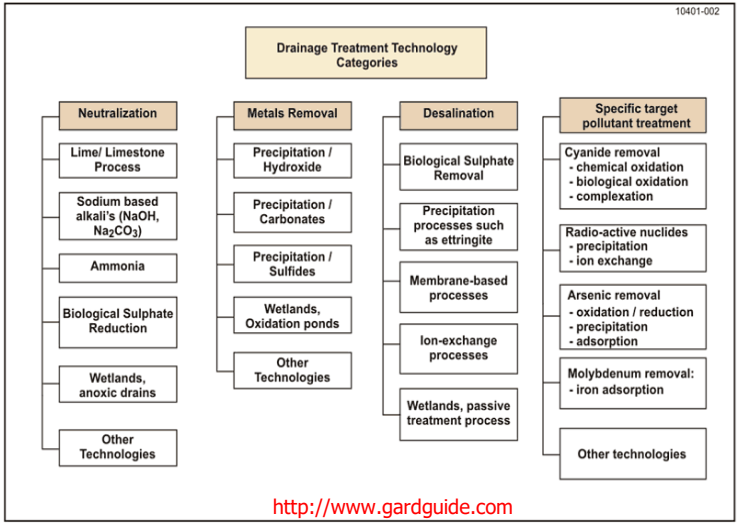
Control and treatment of AMD

Source Control

- Control of either sulfur compounds, oxygen or water
- Grout Curtains/Wall
- Underground Disposal, Encapsulation

Treatment System

- Passive Treatment
- Active Treatment
- Semi-Active Treatment



Definition

Passive treatment is the deliberate improvement of water quality **using only naturally-available energy sources(e.g. gravity, microbial energy, photosynthesis)**, in systems which **require only infrequent(albeit regular) maintenance in order to operate effectively over the entire system design life**

from William Pulles of South Africa.
adopted by the European Union's PIRAMID R&D project.
(mine water, 2002)

Passive treatments of AMD

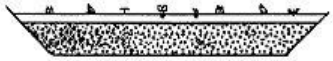
- **Method using natural occurring chemical-biological reactions**
  - need large area due to a long retention time
  - few cases showing uncertain efficiencies
  - weakness for seasonal changes of flow-rate and water quality
  - minimum maintenance expenses

- **Type of treatment systems**
  - Supply of alkalinity
    - Anoxic limestone drain, limestone dumping, diversion well, open limestone channel, limestone pond
  - Aerobic/Settling Systems
    - Settling/oxidation pond, Wetland
  - Vertical flow systems(VFS)
    - SAPS, RAPS

- **Design factor of passive systems**
  - Flow rate, pH, Net acidity, Net alkalinity, Fe species, Al, DO etc.

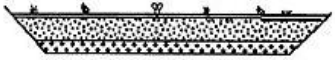
Characteristics of Passive Treatment

A. Aerobic Wetlands



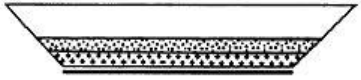
1-3 in. Water
1-3 ft. Organic Matter

B. Anaerobic Wetlands



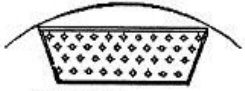
1-3 in. Water
1-2 ft. Organic Matter
.5- 1 ft. Limestone

C. Alkalinity Producing Systems (APS)



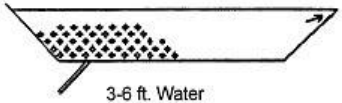
3-6 ft. Water
6-12 in. Organic Matter
1-2 ft. Limestone
Drainage System

D. Anoxic Limestone Drains (ALD)



2-4 ft. Soil
20-40 mil Plastic Liner
surrounding or covering LS
Trench or bed of Limestone

E. Limestone Pond



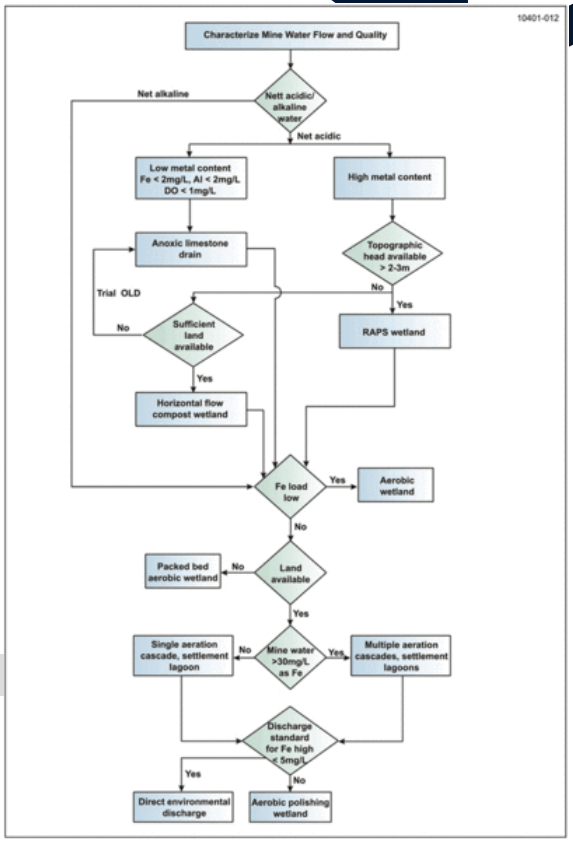
3-6 ft. Water
1-3 ft. Limestone

F. Open Limestone Channel (OPC)

Small or large sized Limestone placed along sides and in bottom of culverts, diversions, ditches, or stream channels.

http://www.wvu.edu/%7Eagexten/landrec/passtrt/pass.jpg

Passive Units	Mine Drainage
Aerobic wetland	Net alkaline drainage
ALD	Net acidic, low Al^{3+}, low Fe^{3+}, low dissolved oxygen drainage
Anaerobic wetland	Net acidic water with high metal content
APS	Net acidic water with high metal content
OLD	Net acidic water with high metal content, low to moderate SO_4

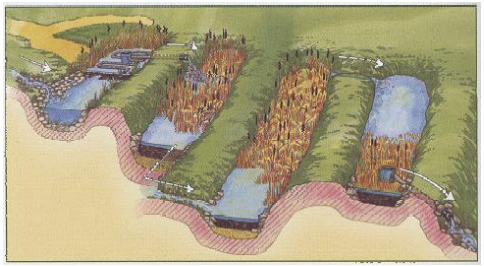


http://www.gardguide.com

Units of Passive Treatment

- **Method Settling Pond / Oxidation Pond(Lagoon)**
  - Set up to oxidize and precipitate metals of net alkaline water

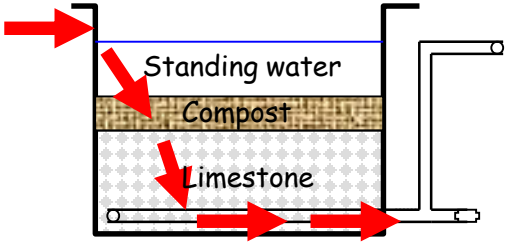
- **Aerobic Wetland**
  - Set up to oxidize and precipitate metals of net alkaline water



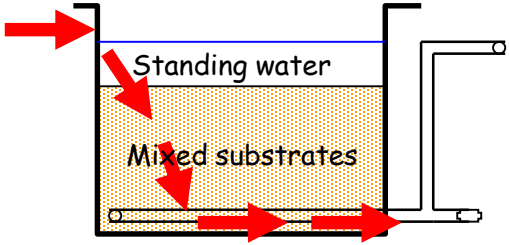
Alkalinity Producing System (APS)

The SAPS consists of an ALD overlaid with organic material; the RAPS consists of an ALD integrated with organic material. (US EPA 2006)

SAPS
(Successive Alkalinity producing System)

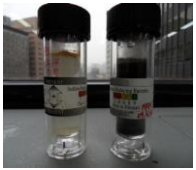


RAPS(or SRB Bioreactor)
(Reducing & Alkalinity producing System)



- Mainly using in coal mine water
- Adding alkalinity and then precipitation to Fe hydroxides
- Thinner organic layer and lower activity of SRB

- Development
  - Short circuiting
  - Permeability
  - Substrates
  - Sludge precipitation



SAPS RAPS

- Using in metal mine and high mineral acidity water
- Adding alkalinity and SRB activity
- Lower permeability than SAPS

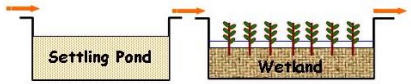
Procedure for the passive systems

Survey and Assessment
(1~2 year)

Pilot test
(1~2 year)

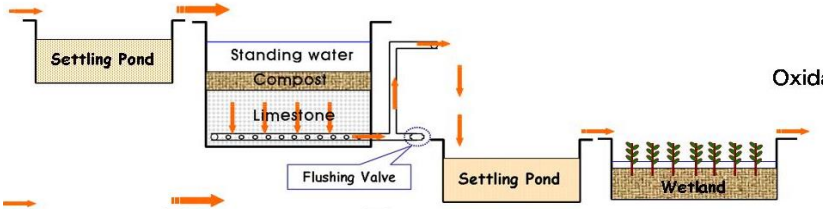
Demonstrative test
(1~3 year)

Applications of passive treatment



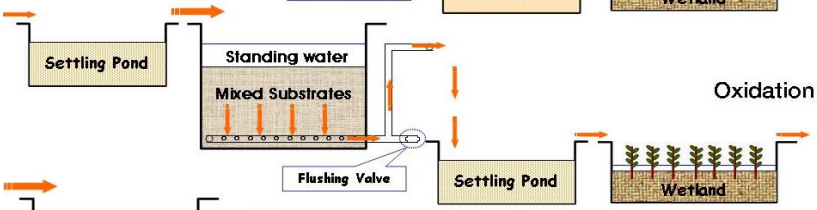
Oxidation pond-Wetland

(Net alkaline, Fe ↓, Base metals↓)



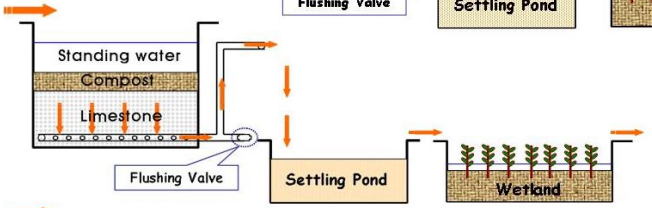
Oxidation pond-SAPS- Settling pond-wetland

(Net alkaline, Fe↑, Base metals↓)



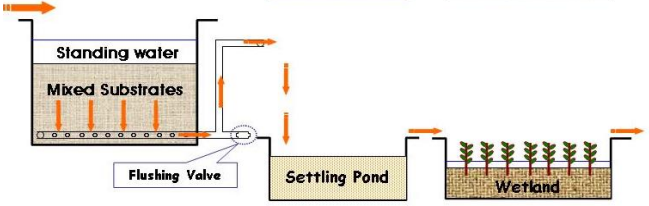
Oxidation pond-Bioreactor- Settling pond-Wetland

(Net alkaline, Fe ↓, Base metals ↑)



SAPS- Settling pond-Wetland

(Net acidic, Fe↑, Base metals ↓)



Bioreactor-Settling pond-Wetland

(Net acidic, Fe↓, Base metals ↑)

Case of Passive treatment Systems (Korea)

Definition

Active treatment is the improvement of water quality by methods which require ongoing inputs of artificial energy and/or (bio)chemical reagents

(mine water, 2002)

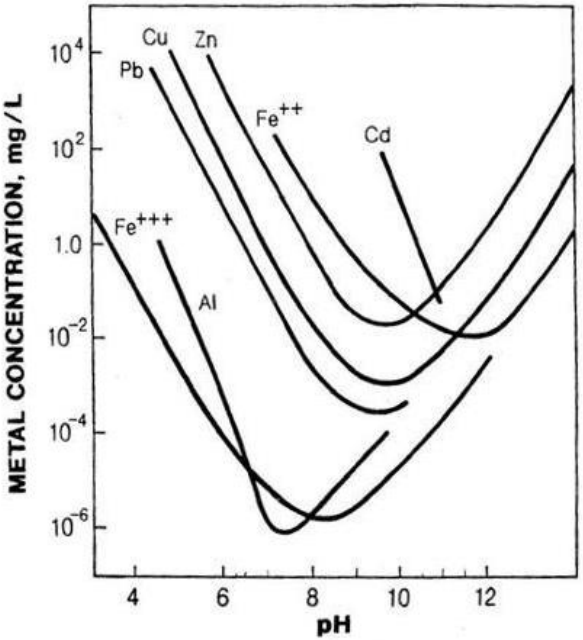
Characteristics of Active Treatment

- Use of chemical properties of most heavy metals in AMD that can precipitate at pH 6~9

metal	Fe^{3+}	Cu^{2+}	Zn^{2+}	Fe^{2+}	Cd^{2+}	Mn^{2+}
pH	3.5	6.8	8.2	8.5	9.8	10.2

- Possible to treat high volume of water and show certain efficiencies
- Need sustainable large maintenance expenses
- Possible to have effective management for seasonal flow-rate changes
- Conventional and text-book type method for a long time
- General process composed of coagulation and precipitation steps after neutralization

Neutralization and Precipitation



Metal Hydrolysis (Aubé and Zinck, 2003)

$$CaO + H_2O \Rightarrow Ca(OH)_2$$
$$Ca(OH)_2 \Rightarrow Ca^{2+} + 2OH^-$$

$$Al^{3+} + 3OH^- \Rightarrow Al(OH)_3$$
$$Co^{2+} + 2OH^- \Rightarrow Co(OH)_2$$
$$Cu^{2+} + 2OH^- \Rightarrow Cu(OH)_2$$
$$Fe^{2+} + 2OH^- \Rightarrow Fe(OH)_2$$
$$Fe^{3+} + 3OH^- \Rightarrow Fe(OH)_3$$
$$Ni^{2+} + 2OH^- \Rightarrow Ni(OH)_2$$
$$Pb^{2+} + 2OH^- \Rightarrow Pb(OH)_2$$
$$Zn^{2+} + 2OH^- \Rightarrow Zn(OH)_2$$

Chemical reagents

Neutralizers

- Sodium hydroxide, calcium oxide, slake lime, sodium carbonate, ammonia, etc

Flocculants

- Iron sulfate, alumium sulfate, sodium aluminooxide, polymer, etc

Oxidants

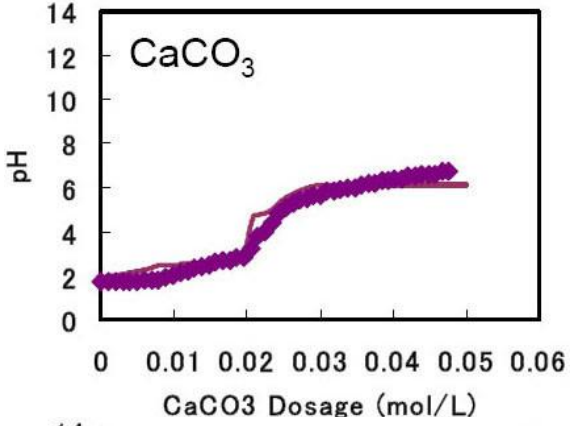
- $Ca(ClO)_2$, $NaClO$, CaO_2, $KMnO_4$, H_2O_2 etc

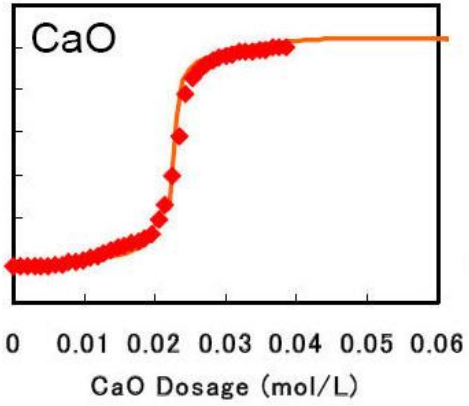
Comparison of Properties of Neutralizer

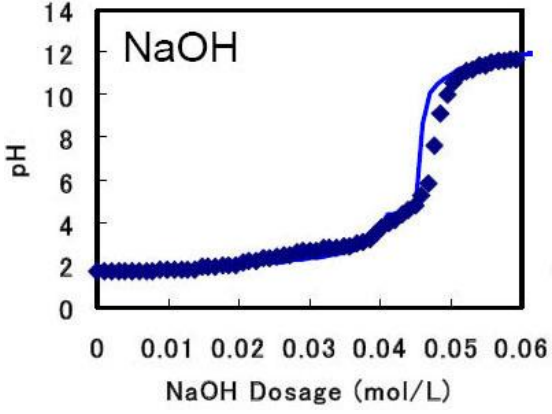
type	Solubility	Dewaterability	Reaction Speed	Neutalization	Expense	Conversion factor	Neu. Capacity
$Ca(OH)_2$	○	△	○	○	△	0.75	90%
CaO	○	△	○	○	○	0.56	90%
$CaCO_3$	△	◎	△	△	◎	1	30%
NaOH	◎	×	◎	◎	×	0.8(s.) 784(20%) 256(50%)	100%
$Mg(OH)_2$	△~○	△~○	△~○	○	△~○	-	-
MgO	△ ~○	△~○	△~○	○	△~○	-	-

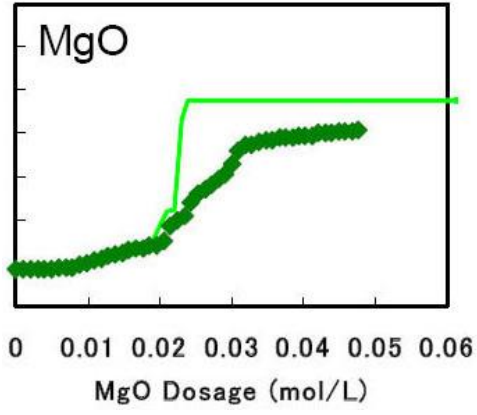
* Expense comparison of kmol of OH- equivalent:
  $CaCO_3$($0.69), $Ca(OH)_2$($2.64), NH_3($5.61), Na_2CO_3($15.16), NaOH($22.56)

pH profiles with the injection of neutralizers

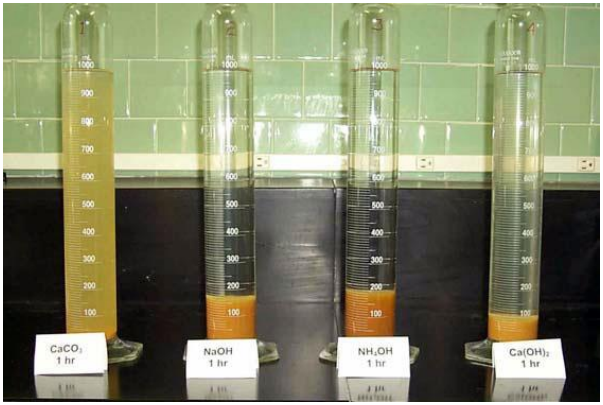


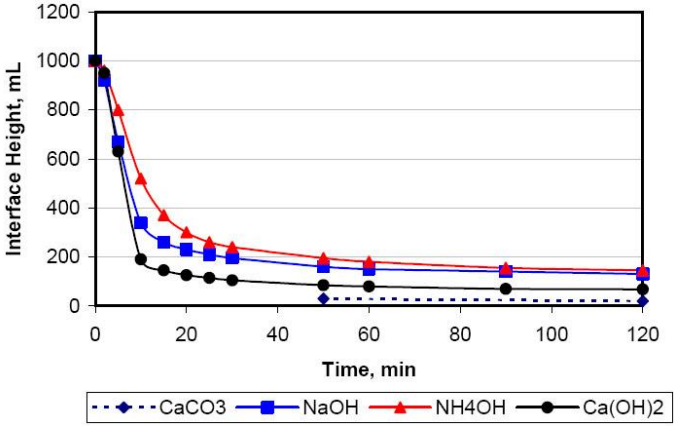




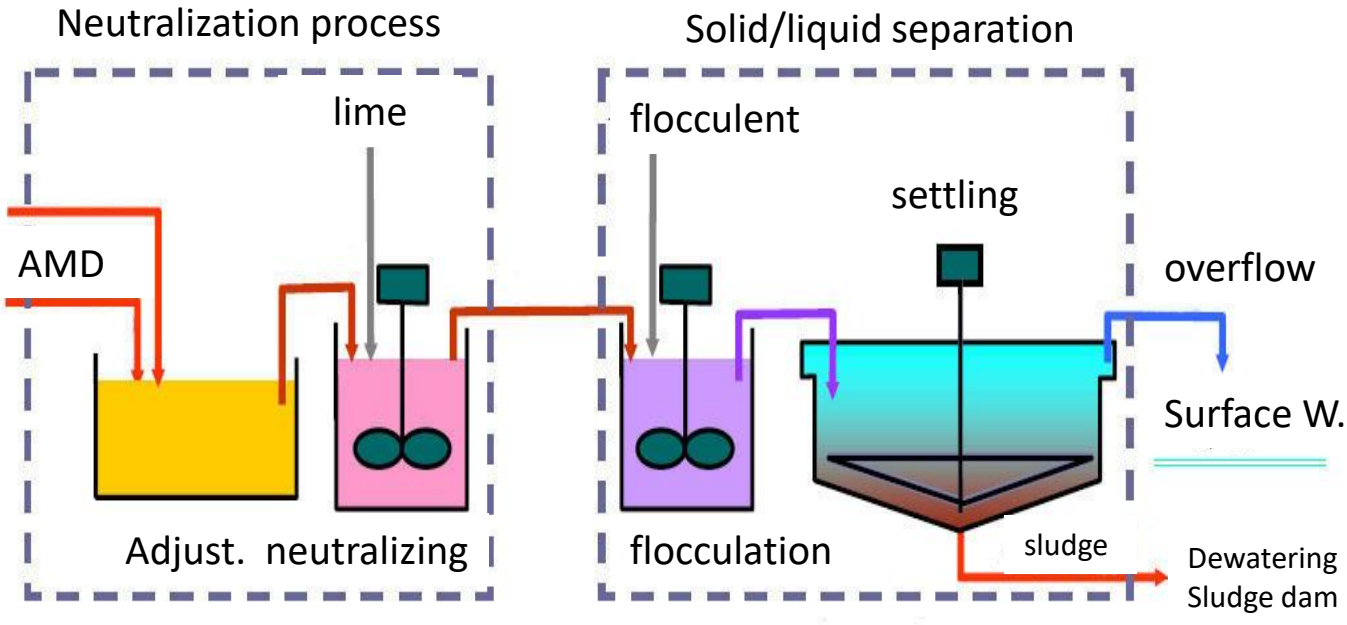


Precipitations depending on neutralizers





Conventional Chemical Treatment System

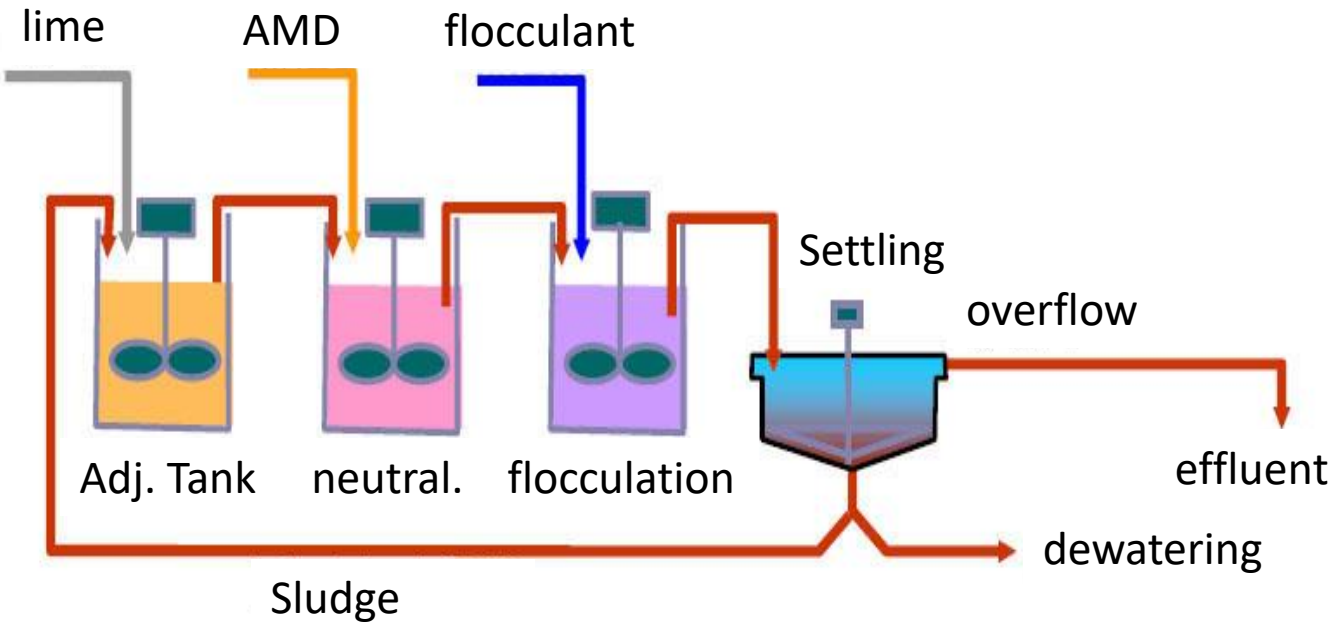


low density sludge → high cost

Sludge Return Process

- **Suggested as a method for sludge reduction**
  - Use partial sludge as a seed of precipitation through recycling into the process
- **Advantages**
  - Use non-reactive lime
  - Increase the sludge density
  - Improve the liquid-solid separation
  - Reduce the scale of reactor
- **Process**
  - MMA process (simple sludge recyle)
  - SRR process (sludge return reverse)
  - HDS (High Density Sludge) process
  - Geco process (MMC process)

HDS (High Density Sludge Process)



Lime + Return Sludge → AMD
Sludge Density : 20%

Case of active system (Korea)

03

Introduction of Sanha E&C and their Technology

Business area

Soil Remediation

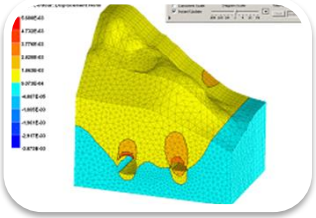
- Heavy Metal, Asbestos, Petroleum Contaminated Soil Remediation
- Ground Water Remediation

Mine Reclamation

- Mine Drainage Treatment
- Tailing Loss Prevention
- Mine subsidence Prevention

R&D

- Environmental ENG.
- Geotechnical ENG.
- Mineral & Resource ENG.



Geotechnical Works

- Tunnel
- Slope
- Monitoring, ETC.

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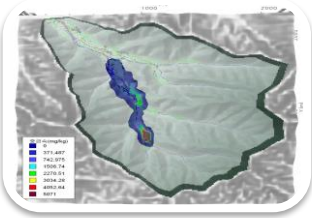
Investigation



Design

Construction

Consulting

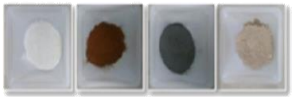
Business experience

Main project by business area

Soil remediation (54case)	• Design for soil improvement restoration in GM mine area('22) • Restoration of soil Improvement in HGS mine area('22)
Improvement of Polluted water quality (25case)	• water quality improvement project of TB mining Industry('22) • Coal mine(BR) water purification facility installation('22)
Tailings loss prevention(14case)	• Feasibility study for the construction of tailing dam('22) • Complete renovation of mineral waste storage facilities ('22)
Prevention and recovery of subsidence (150case)	• Investigation of the ground stability of the SB mine ('22) • Design service of ground reinforcement DS mine area ('22)
KOMIR R&D (22case)	• Development of soil remediation methods depending on the arsenic contamination type at the abandoned coal mine('21)
Ministry of Environment R&D (10case)	• Advanced purification technology based on reduction materials('22) • Development of optimal stabilizers considering heavy metal contamination ('22) • Study on the stabilization of arsenic and heavy metals in China ('18)
Overseas Project (8case)	• A study on adsorbent for water treatment in rare earth extraction in china('18) • Consulting on Malaysia's RHT mine closer plan ('17) • Consulting on recovering mining in Malaysia's Mamut mine ('09)

Soil remediation

- Precise investigation and feasibility study of contaminated soil
- Design & Construction for improvement, restoration and remediation of contaminated soil
- R&D such as in-situ remediation and soil stabilization technology
- Development and sales of soil stabilizer(EcoSta) for heavy metal contaminated soil



EcoSta®

Core Technology – Soil remediation

Soil stabilizer for remediation of heavy metal contaminated soil

Optimized eco solution
for contaminated soil remediation

EcoSta®

- Various types for soil condition, pollution materials, usage plan
- Composed by eco friendly materials / Excellent constructability
- Effectiveness verification through National R&D project

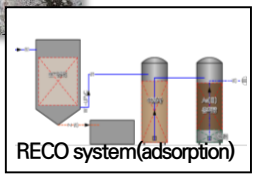
Mine drainage treatment

- Feasibility study of mine drainage treatment
- Design and construction of natural purification facility
- Design and construction of semi active purification facility
- Development and sales of As, Heavy-metal adsorbent $RECO_{LDH}$, $RECO_{CMDS}$

RECO LDH

RECO CMDS

Passive treatment



Core Technology – Water treatment

Arsenic - Heavy metal contaminated water treatment system

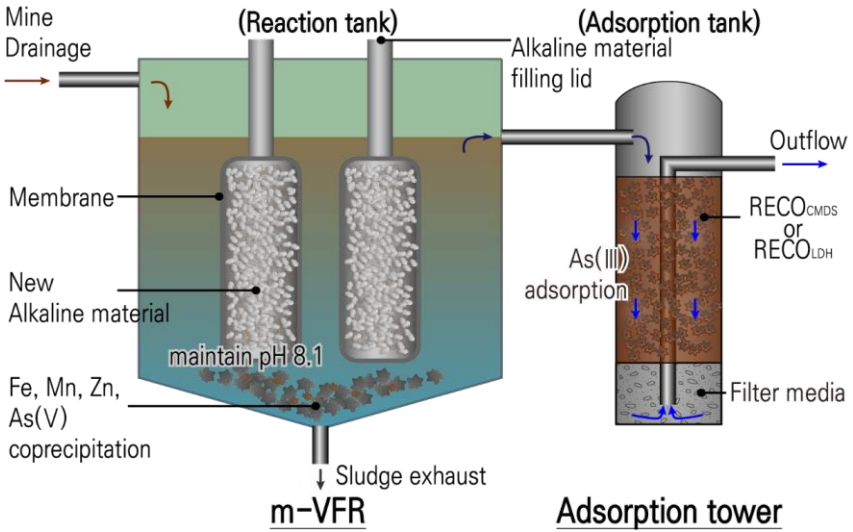
Absorbent

RECO LDH

RECO CMDS

- Water treatment for polluted groundwater, mine drainage, wastewater
- Suitable for small scale processing / Excellent maintainability
- Effectiveness verification through National R&D project

–Water treatment system conceptual diagram–

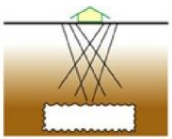


Tailing loss prevention

- Stability assessment of tailing retention area
- Design and construction of tailing retention area
- Design and construction of tailing loss prevention
- Research and development of technology for detoxification and recycling of tailings

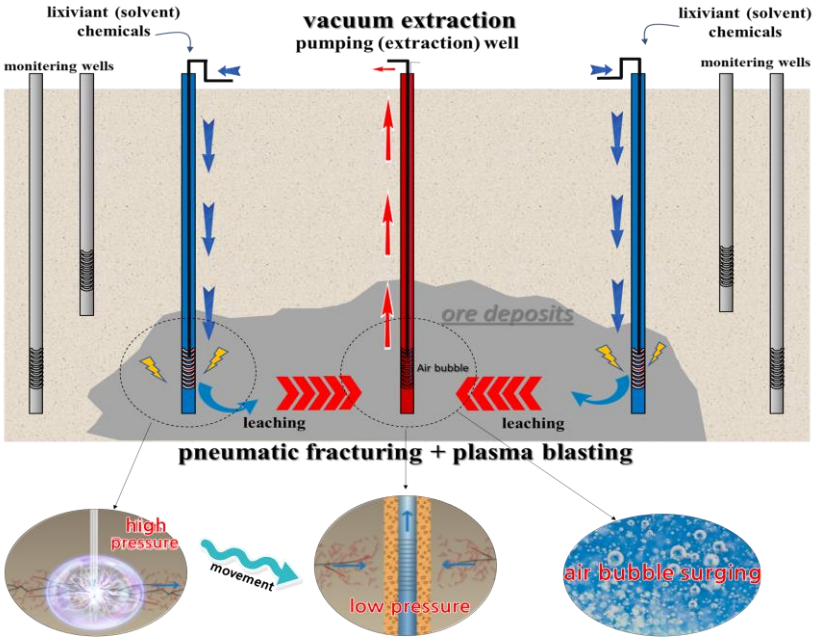
Mine subsidence prevention

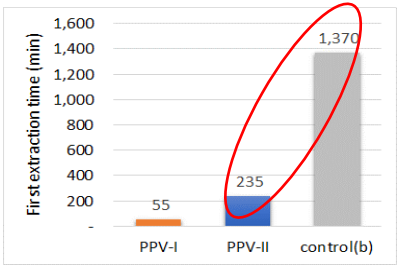
- Basic and precise survey of the ground stability
- Design and construction for mining ground reinforcement
- Ground subsidence monitoring
- Development and sales of Bulbous micro pile method for ground reinforcement

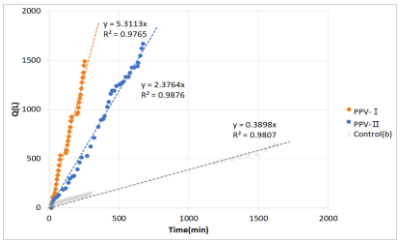


Core Technology – In situ leach mining

In Situ Leach mining using PPV(Pneumatic fracturing+Plasma blasting+Vacuum)







Mine closure plan

- Key objectives of mine closure plan

Public health & safety

Alleviation or elimination of environmental damage

Land rehabilitation

Social and economic benefits

- Consideration of mine closure plan

Physical stability

Geochemical stability

Land use

Sustainable development

- Mine closer plan task for prevention of mining damage

Improvement of polluted water quality

Tailing & Waste loss prevention

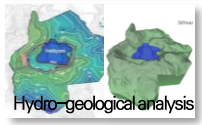
Ground & Slope stability

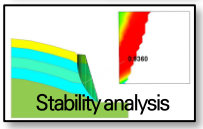
Soil remediation

Mine closure plan

Consulting of mine closure plan

Document study	Mine status data, Mining operation plan, Map, ETC.
Develop Detailed plan	Detail plan review, Discuss with mining developer
Field investigation	Sampling of soil, rock, water, Face mapping, Field test
Mineral, soil, water analysis	ICP, AA test and ETC.
Laboratory test	AMD test, XRD XRF SEM, Colum test, Lab scale pilot test
Modeling & Simulation	Hydro-geological analysis, Stability analysis
Option study	Reclamation plan for Mine pit, Tailing dam, Waste area, ETC.
Presentation for Gov.	Economic feasibility, Eco-friendliness, Workability review
Monitoring & Pilot test	Water, Ground monitoring, Field scale pilot test





Q&A

Korea Mine Rehabilitation and Mineral Resources Corp.
KOMIR

Korea Mine Rehabilitation and Mineral Resources Corp.
KOMIR