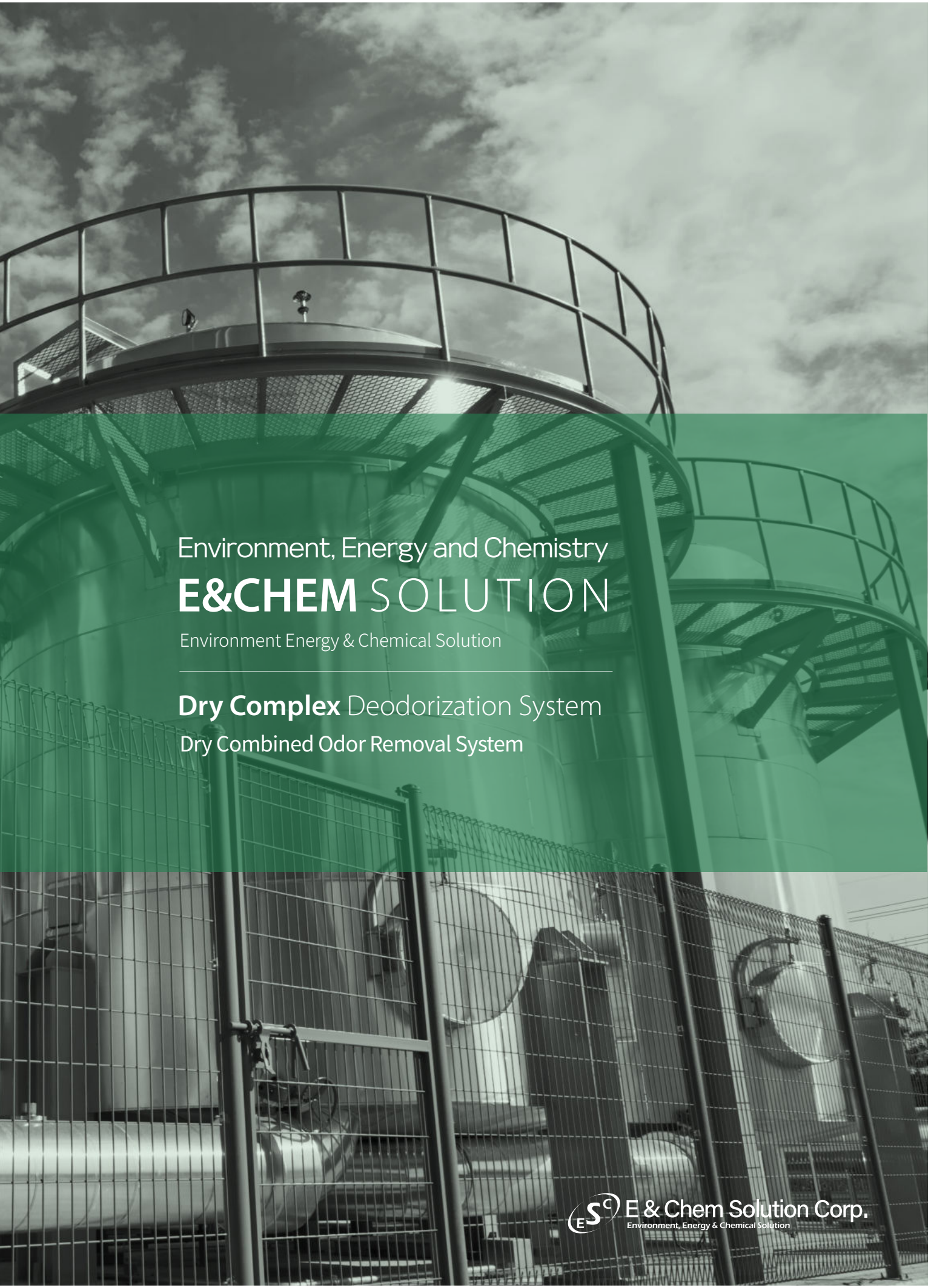


Environment, Energy and Chemistry

# E&CHEM SOLUTION

Environment Energy & Chemical Solution

## **Dry Complex** Deodorization System

Dry Combined Odor Removal System

E & Chem Solution Corp.

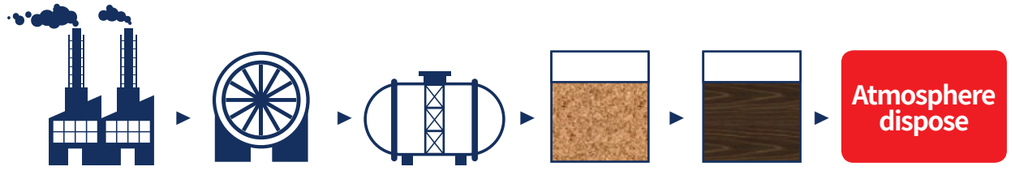
Environment, Energy & Chemical Solution

## The need to remove odors

- Intensifying complaints about odor in residential areas near public treatment facilities
- Reinforcement of odor regulation according to the improvement of citizen's living standard
- It is necessary to remove harmful substances to the human body contained in odorous substances.

* A bad odor is an odor that causes an unpleasant and disgusting feeling to people.

## Schematic diagram of odor removal system




Ammonia and hydrogen sulfide are sequentially removed through a dehumidification process and iron hydroxide-based adsorbent. Then, the voc's are removed through the activated carbon tower and the air is discharged to secure clean air quality.

* VOC's : volatile organic compounds

## Effect of Odor Removal

**Improvement of life quality in residential areas around public facilities**

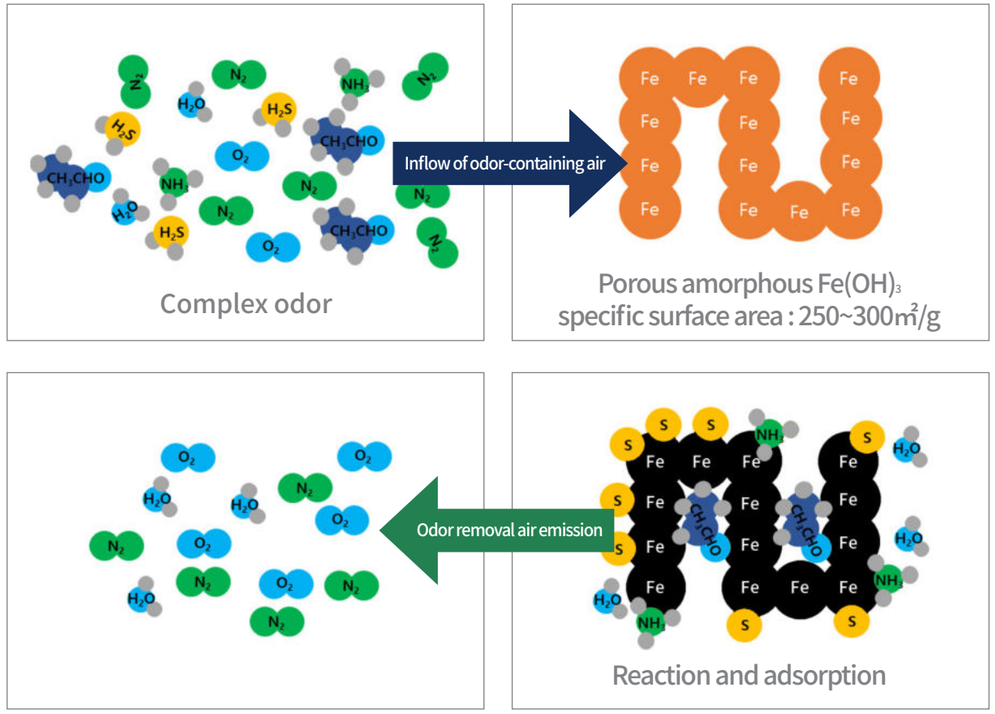
**By preventing the release of hydrogen sulfide and ammonia, VOC's into the atmosphere, the clean air quality is secured**

**Decreases of complaints due to odors and improving working conditions for field works**

**Securing odor source data for complex odor-causing substances and Customized odor removal process design**



## Primary deodorization principle (removal of hydrogen sulfide and ammonia)

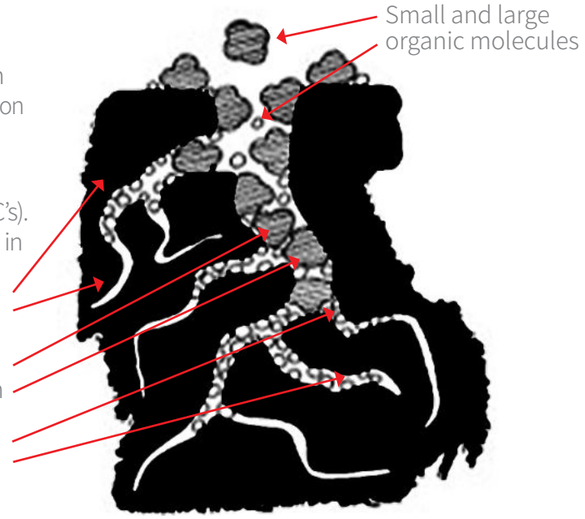



<Removal mechanism of hydrogen sulfide and ammonia>

- Hydrogen sulfide is removed by adsorption reaction through a porous iron hydroxide-based adsorbent. Then, ammonia and some voc's are adsorbed into the formed pores for primary purification.

## Secondary deodorization principle (VOC's removal)

- Physical adsorption purification through high specific surface area of activated carbon
- It has excellent adsorption performance for Mercaptans, hydrocarbons, organic chlorine compounds and aldehydes (VOC's). so it absorbs the components contained in the complex odor




<Activated carbon physisorption principle>

# Dry complex odor removal system

## Process Features

- Removal of ammonia and moisture using dehumidification process
- Removal of hydrogen sulfide using iron hydroxide
- Removal of complex odors by removing aldehydes using activated carbon

### Existing odor removal

- Short adsorbent replacement cycle due to wetting
- Unaware of the need for dehumidification
- Low removal rate due to low reactivity between hydrogen sulfide and iron oxide.
- High operating cost due to short replacement cycle
- The application of a multi-stage chemical cleaning (scrubbing) tower increases costs such as facility investment, chemicals, and electricity.
- A large amount of waste liquid and waste water generated by chemical cleaning through scrubbing
- Requires additional facilities to prevent the generation of nitrogen oxides (NOx) during combustion deodorization and high operating costs due to fuel use

### Dry odor removal

- A dry process through dehumidification to prevent deterioration of adsorption capacity due to wetting
- 60% reduction in dehumidification cost through two-stage heat exchange dehumidification
- Since hydrogen sulfide is separately removed by iron hydroxide($Fe(OH)_3$), it exhibits excellent compound odor removal performance compared to the existing process
- Reduction of initial installation cost due to minimum residence time
- Reduction of operating costs by using minimal power
- Unmanned operation possible and easy on-site maintenance
- No wastewater generated by the use of chemicals





# Sludge Concentration Tank-derived Odor Removal Demonstration Test at Jungnang Water Regeneration Center


## Conditions for removal of odors

- **Demonstration test capacity** : 400 L/min
- **Hydrogen sulfide($H_2S$)density** : 1~4 ppm
- **Complex odor dilution Time** : 100~60,000 times
- **Test bed size** : 5L * 2part(top/bottom configuration)
- **Odor Stream** : Up-stream method

Existing odor removal equipment
(4.7m³ * 3part = 14.1 m³)

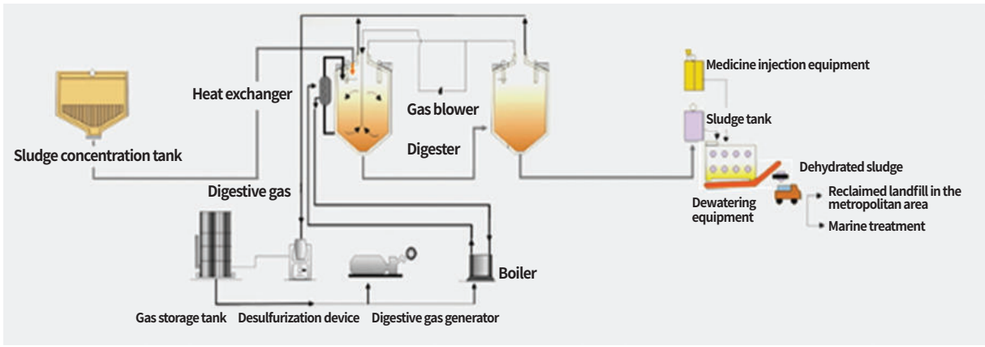
Demonstration facility
(5L * 2part = 10L)

Odor stream

## Composition

2nd deodorization
Impregnated activated carbon

1st deodorization
DeHyS-250




Odor generation and verification point

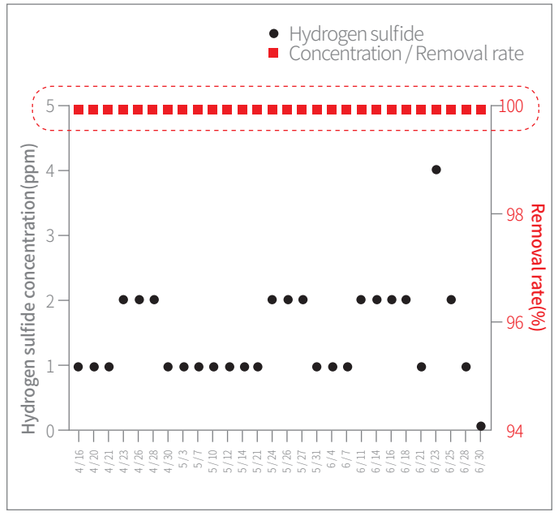
Inlet

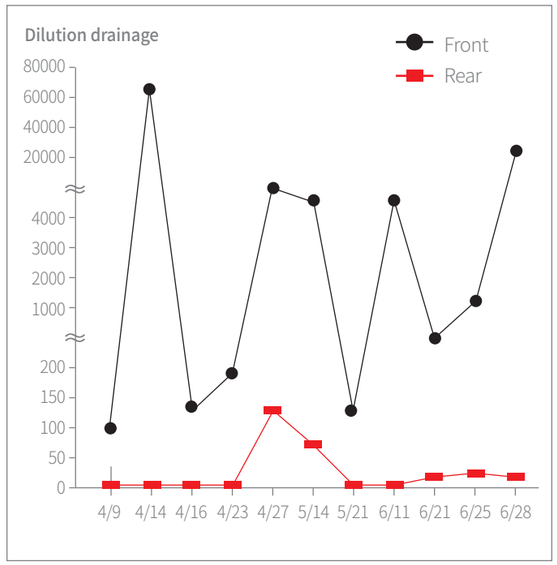
1st deodorization bed

2nd deodorization bed

**Complex odor measurement and analysis** : Korea EMC

## Concentration Tank-derived Odor Removal Demonstration Test at Jungnang WWTP




### Demonstration test driving conditions

- **Space velocity** : 4,800hr$^{-1}$
- **Residence time** : 0.75 sec
- **Throughput** : 400 L/min

### Hydrogen sulfide (odor-causing substance) removal rate

- 100% removal
  (Operation period: 49 days)

### Diluted drainage after inflow of odor and treatment

- **Dilution of inflow odor** :
  100 to 60,000 times
  - Influence of sludge loading situation and weather
- **Dilution of odor after treatment :**
  10~150times
  - Results measured through air dilution sensory method
- **Development of dry complex odor removal process with excellent odor removal performance**

| Division | Inflow | 1st deodorization | 2nd deodorization |
|---|---|---|---|
| Dilution factor | 448 | 207 | 30 |

※ Complex odor measurement and analysis progress (Measuring Agency : Korea EMC)

### Odor type

- Concentration tank-derived occurrence

### Field test conditions

- 400 L/min, Operating hours (49 days)

### Processing criteria

- Hydrogen sulfide less than 1ppm, Dilution drainage less than 100

### Sampling location

- Inflow, primary (DeHyS-250), secondary (impregnated activated carbon)

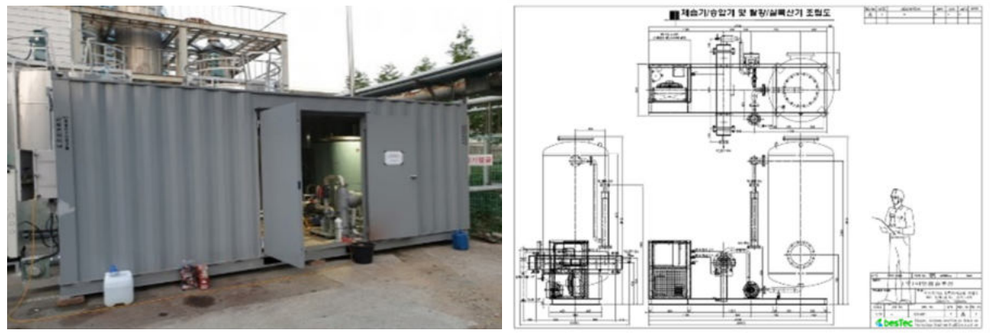


## Digested Sludge Reservoir-derived Odor Removal Demonstration Test at Tancheon Water Regeneration Center


### Conditions for ingress of odors

- **Demonstration test capacity** : 2,500 L/min
- **Hydrogen sulfide ($H_2S$)density** : 10~40 ppm
- **Complex odor dilution drainage** : 1,000~10,000 times
- **Test bed size** : 500L
- **Residence time** : 12sec
- **Odor inflow method** : Up-stream method

<Digestive Thalis Reservoir at Seoul Tancheon Water Regeneration Center → Pilot-plant about 70m>

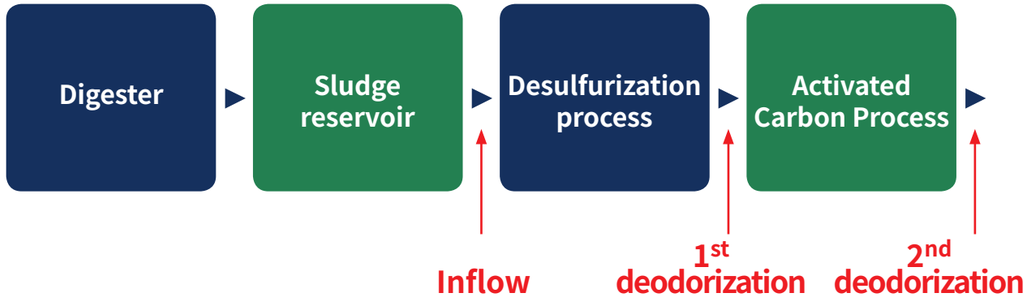


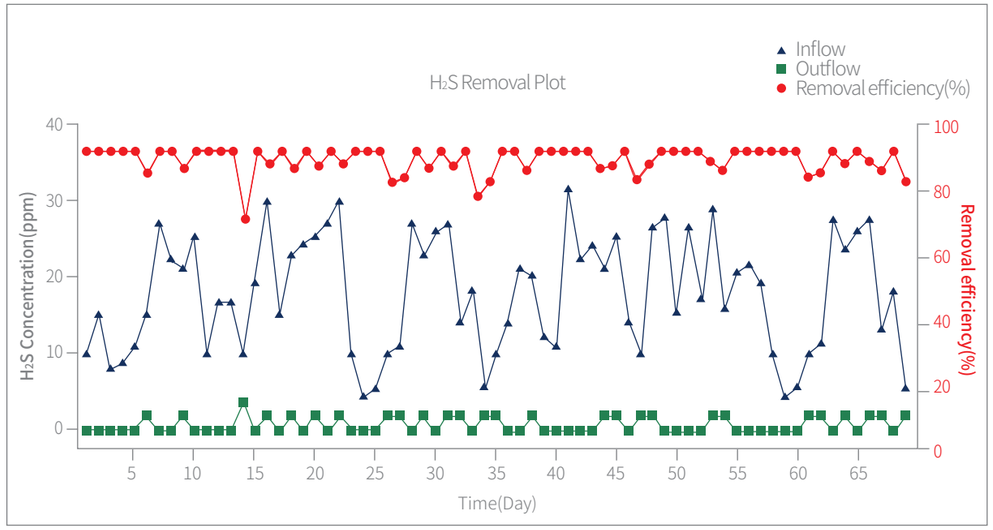
<Installation site appearance & design>



Dry Complex Deodorization System

## Digested Sludge Reservoir-derived Odor Removal Demonstration Test at Sludge storage tank




### Hydrogen sulfide inlet and outlet concentrations

- **Average inlet concentration(ppm)** : 18.16
- **Average outlet concentration(ppm)** : 0.41
- **Average hydrogen sulfide removal rate(%)** : 97.76

| Division | Inflow | 1st deodorization | 2nd deodorization |
|---|---|---|---|
| Dilution drainage | 3,000 | 1,000 | 448 |

※ Complex odor measurement and analysis progress (Measuring Agency : Korea EMC)

### Odor type

- Digested sludge reservoir

### Field test conditions

- 2,500 L/min

### Processing criteria

- Hydrogen sulfide less than 1ppm, Dilution drainage less than 100

### Sampling location

- Inflow, After dry adsorption, After wet adsorption



## Proposal of odor removal demonstration test in sewage treatment plant

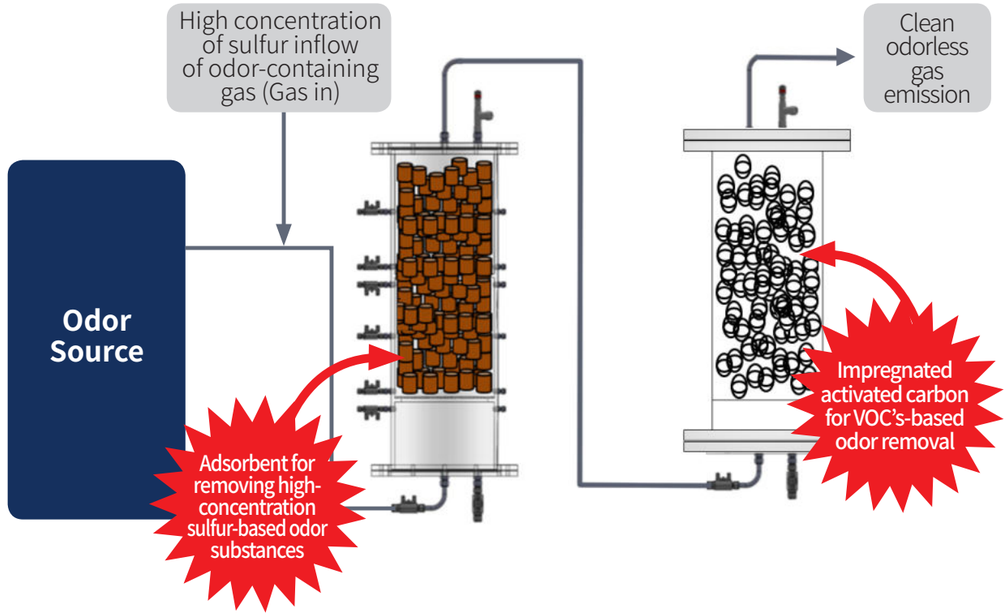
### Expected odor conditions

- **Expected hydrogen sulfide($H_2S$) concentration** : 1~40 ppm
- **Expected ammonia ($NH_3$) concentration** : 1~60 ppm
- **Expected dilution factor of inflow complex odor** : 1,000~60,000 times

### Demonstration test driving conditions

- **Demonstration test capacity** : 10 CMM, 8 HP
- **Test bed size** : 1.0 $m^3$
- **Odor inflow method** : Up-stream method (Utilize an air blower)
- **Residence Time** : 6 sec
- **Space Velocity** : 600 $hr^{-1}$

## Schematic diagram of odor removal system




A odor removal system inhales the complex odor diluted in the air from the odor source. After the primary and secondary deodorization processes are carried out through the dehumidification process, the odor-free air is discharged. However, in the case of dry gas, dehumidification facilities are excluded.

## Odor Removal Target

| Division | Removal rate | 1st deodorization | 2nd deodorization |
|---|---|---|---|
| Hydrogen sulfide(ppm) | 99% | 1 or less | 1 or less |
| Complex odor | 80% | 1,000 or less | 300 or less |
| Moisture | - | 50RH% or less | 50RH% or less |



Dry Complex Deodorization System

Environment, Energy and Chemistry

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Environment, Energy and Chemistry

# **E&CHEM** SOLUTION

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## **Catalytic** Desulfurization System

Desulfurization catalyst system

E & Chem Solution Corp.

Environment, Energy & Chemical Solution

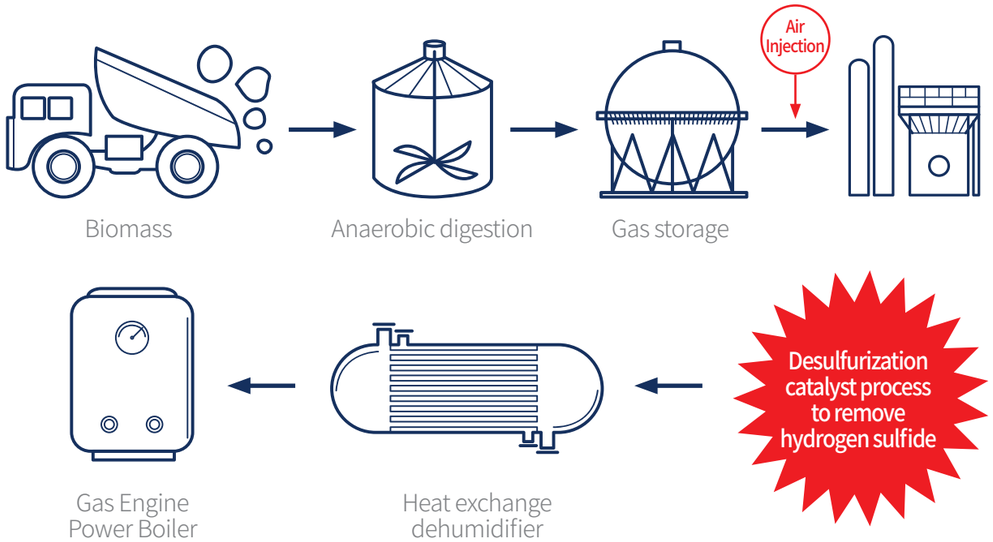
## Iron oxide($Fe_2O_3$) catalyst

CATALITE®

## Desulfurization Catalytic Reaction Mechanism

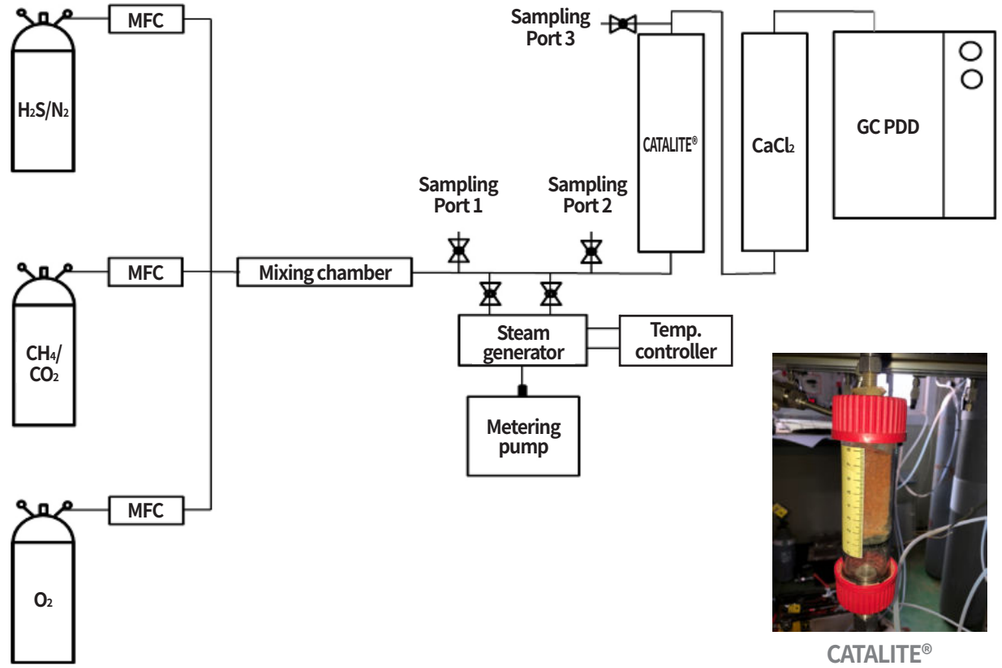
| | |
|---|---|
| Iron oxide ($Fe_2O_3$) | $3CO_2 + 3H_2S + H_2O + 3O_2 \rightarrow 2CO_2 + H_2SO_4 + 2S + H_2CO_3(CO_3^{2-} + 2H^+) + 2H_2O$ |

## Schematic diagram of biogas production facility




## Hydrogen Sulfide($H_2S$) Desulfurization Catalyst Test I

| Item | | Unit | CATALITE® | Remarks |
|---|---|---|---|---|
| Dilution drainage | 3,000 | wt% | 30 or more | Catalytic reaction experiment result criteria |





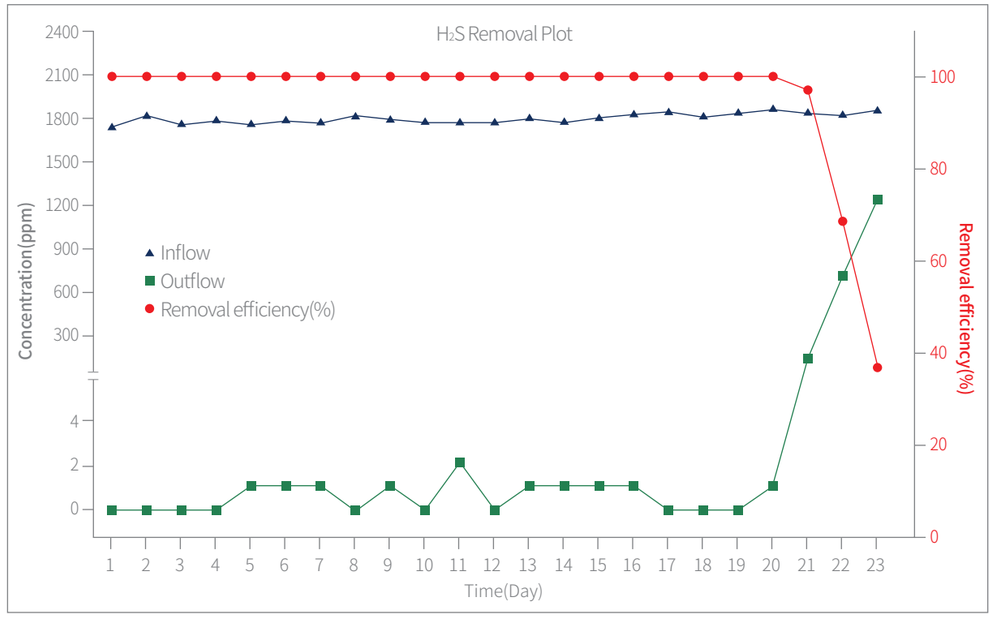

CATALITE®

### Experimental Conditions

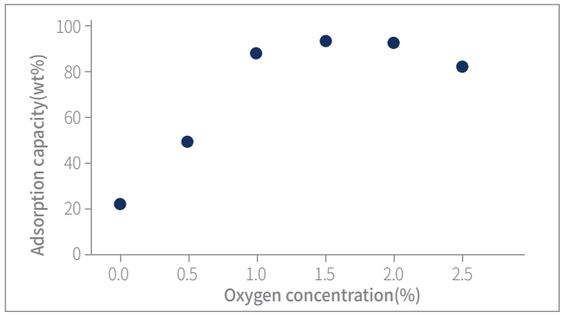
- $H_2S$ = 1,600 ~ 1,800 ppm
- $O_2$ = 1 ~ 2%, $O_2$
- **Humidity** : RH 100%
- **Bed volume** : 100ml (Capa. : 36g(60ml))
- **Flow rate** : 50ml/min
- **Space Velocity = 50 $hr^{-1}$**
- Contact time = **72 sec**

# Hydrogen sulfide($H_2S$) Desulfurization Catalyst Test II

## Hydrogen sulfide removal efficiency by desulfurization catalyst

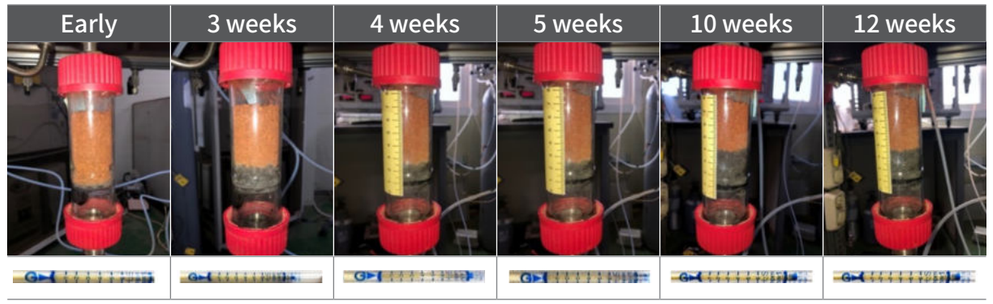



## Desulfurization catalyst removal efficiency with oxygen inflow concentration




| Oxygen concentration(%) | Adsorption capacity(wt%) |
|---|---|
| 0.1 | 27.5 |
| 0.5 | 42.1 |
| 1.0 | 85.0 |
| 1.5 | 90.0 |
| 2.0 | 87.0 |
| 2.5 | 80.4 |

## Desulfurization catalyst discoloration




**Detection of $H_2S$ less than 1ppm as a result of checking the detector tube**

# Biogas pretreatment site test results I

## Byeolnae Food Waste Clean Center

- **Sewage treatment capacity** : 275,000 ㎥/day
- **Biogas generation** : 8,000㎥/day
- **Hydrogen sulfide($H_2S$)** : 5,000 ppm or more
- **Siloxane** : around 50 ㎎/㎥




- **Biogas Application** : biogas production for use in boilers and incineration
- **Process gas concentration** : hydrogen sulfide 10 ppm or less
- **Sampling location** : 1 front and 1 rear of test bed respectively
- **Conditions for field testing** : 15L/min, Average hydrogen sulfide concentration (approximately 5,000 ppm), operating time (720 hr)
- **Air injection** : 500 ml/min, inflow composition($CH_4$ 60%/$CO_2$ 30%/$H_2S$ 0.5%/$H_2O$ 5%/$O_2$ 1%)

※ **Goal** : Hydrogen sulfide removal rate of 99% or higher (99.5% or higher)

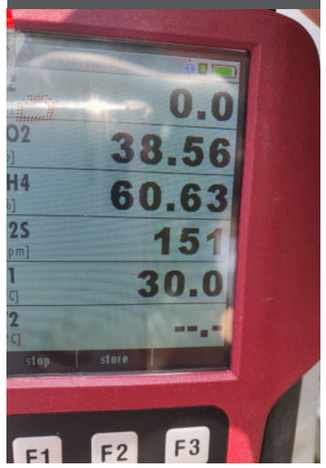


Catalytic Desulfurization System

# Biogas pretreatment site test results II

## Goyang Biomass energy facility

- **Food waste treatment capacity** : 260 ton/day
- **Biogas generation** : 20,000~24,000㎥/day
- **Hydrogen sulfide($H_2S$) Concentration** : around 150 ppm


| Desulfurization equipment | Inflow concentration | Outflow concentration |
|---|---|---|
|  |  |  |

- **Biogas Usage** : Utilization of Urban Gas in Goyang City
- **Processing gas concentration** : 10 ppm or less in hydrogen sulfide (urban gas supply line 0.9 ppm))
- **Sampling Location** : Desulfurization Facility Shear and Urban Gas Supply Line
- This is the first supply facility for the desulfurization catalyst.
- Air supply blower for catalytic reaction maintains oxygen concentration according to biogas flow rate.



## Memo

Catalytic Desulfurization System

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Environment, Energy and Chemistry

# E&CHEM SOLUTION

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## Dry System for **VOC's Removal**

Dry system for removing VOC's

E & Chem Solution Corp.

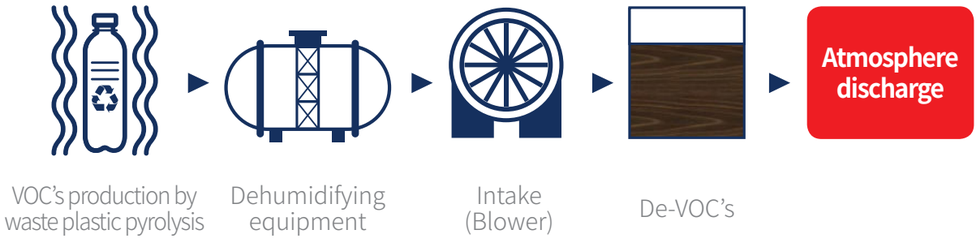
Environment, Energy & Chemical Solution

## Necessity to Remove Waste Plastic VOC's

- VOC's line of odor complaints intensified near waste plastic recycling facilities
- When discharged into the atomphere due to the occurance of a large amount of VOC's, air qulity deteriorates
- Large amounts of harmful organic compounds are discharged during melting of waste plastics.

* VOC's are volatile organic compounds including emission regulations and odorous substances.

## Flow Chart of Waste Plastic Recycling VOC's Removal System




When recycling waste plastics, VOC's generated by thermal decomposition are absorbed. And the high boiling point VOC's are removed from condensate through the dehumidification facility and the low boiling point VOC's are removed from the VOC's through an activated carbon tower and discharged to the atmosphere to secure clean air quality

* VOC's: Volatile Organic Compounds

## Effect of removing VOC's

**Improvement of life quality in the residential areas around public facilities**

**By preventing the release of VOC's into the atmosphere, the generation of fine dust is suppressed and clean air quality is secured**

**Decrease of complaints due to odors and improving working conditions for field works**

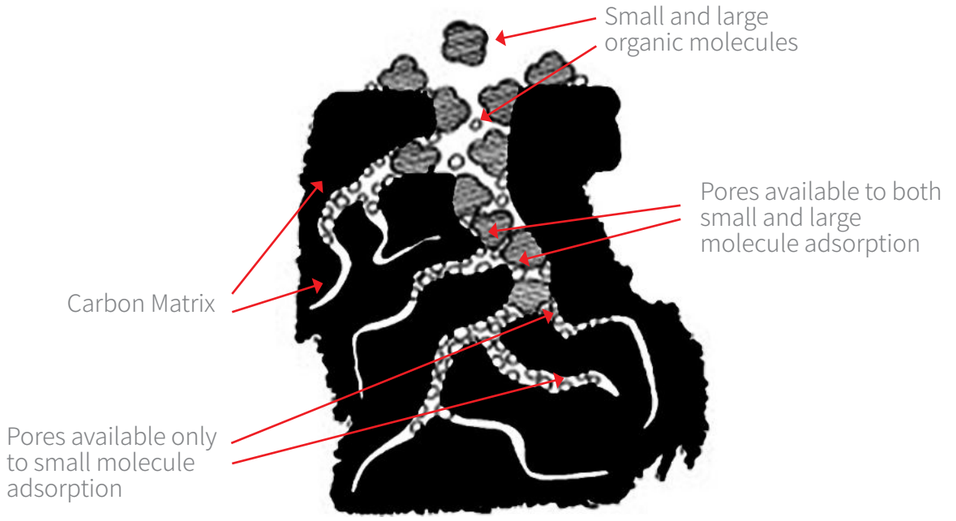
**Securing odor source data for complex odor-causing substances and Customized odor removal process design**





## VOC's removal principles

- Physical adsorption purification through high specific surface area of activated carbon
- It has excellent adsorption performance for mercaptans, hydrocarbons, organochlorine compounds and aldehydes. So it absorbs the components contained in complex odor



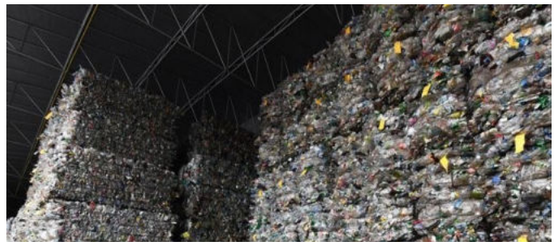

<Activated carbon physisorption principle>

## Types of VOC's occurred in Waste Plastic recycling processe

<VOC's occurrence according to the type of recycled plastic by the Pocheon's company>

| Type | Substance containing |
|---|---|
| PP | Propane, Polymeric carbon compounds, etc. |
| PE | Ethane, Polymeric carbon compounds, etc. |
| PS | Styrene, Toluene, Ethylbenzen, etc |
| ABS | Butadiene, Styrene, Toluene, Ethylbenzene, etc |

## Odor removal test for waste plastic recycling in Pocheon



### Existing inflow conditions

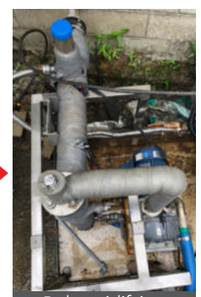
- Existing facility handing capacity : approximately 100 $m^3$/min
- Types of recycled plastics : PP, PE, PS, AB, etc


Existing VOC's removal facility($30m^3$)

Generation of large amounts of VOC's fume

Occurrence of high concentrations of VOC's

High-concentration VOC's intake



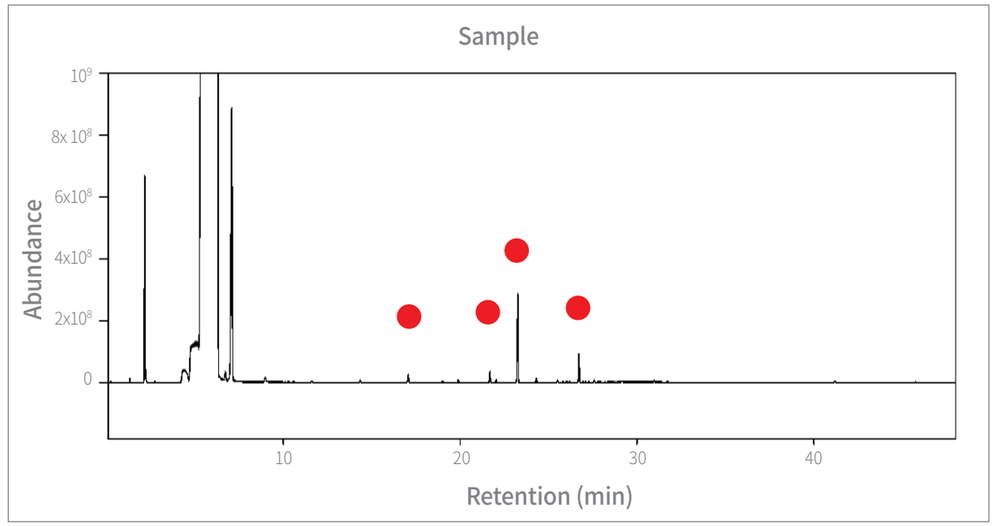
Dehumidifying equipment and blower

De-VOC's equipment

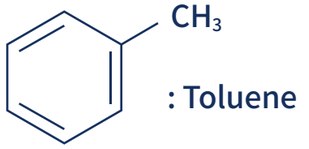
- **Empirical test operating conditions**
  **Space velocity** : 300 $hr^{-1}$ / **Residence time** : 12 sec / **Throughput** : 500 L/min
- **VOC's removal rate(Styrene, Toluene, Ethylbenzene)**
  **100% removal** (operating period: 60 days)

## Qualitative analysis of plastic recycling heat process

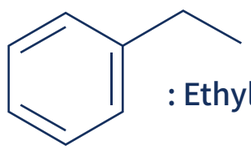
### Request for GC-MS (Seoul National University of Science and Technology) analysis



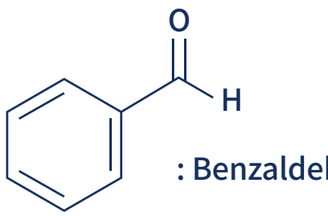

<GC-MS measurement results through hexane absorption method (Qualitative analysis)>



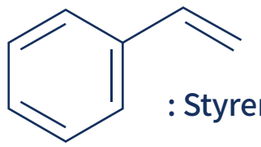

: Toluene



: Ethylbenzene




: Benzaldehyde



: Styrene

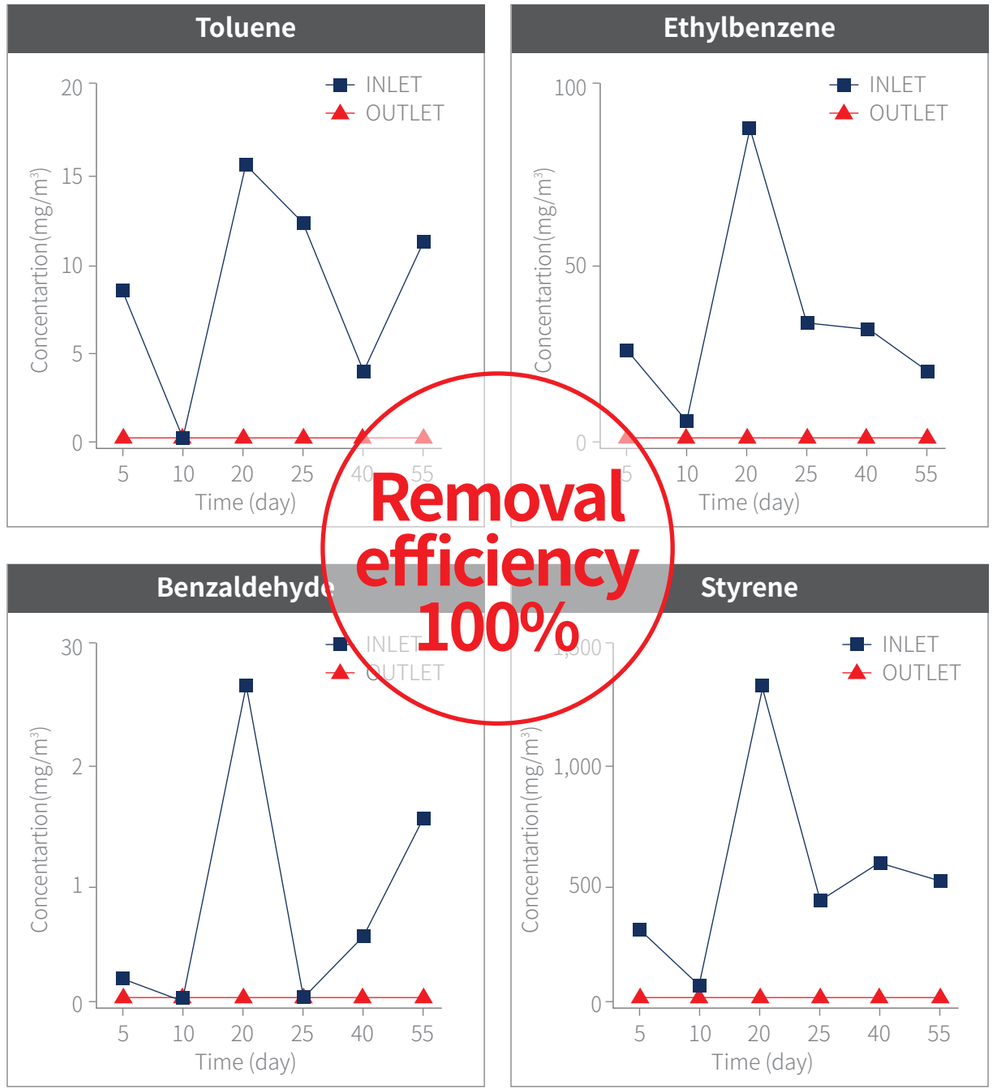
**It mainly consists of the above components and there are many other types of aromatic organic compounds.**





Dry System for VOC's Removal

## PILOT TEST VOC's analysis results




- **Special note**
  - Manufacturer's plastic throughput is not constant
  - unbalanced types of plastics

- **Conclusion**
  - Wide range of influent concentration according to throughput
  - Regardless of the inflow concentration, the removal rate is 100%

## Emission acceptance standard

· Complex odor

| Division | Emission acceptance standard (Dilution Drainage) | | The range of Strict emission acceptance standard (Dilution Drainage) | |
|---|---|---|---|---|
| | Industrial area | Other regions | Industrial area | Other regions |
| Outlet | 1000 or less | 500 or less | 500 ~1000 | 300 ~ 500 |
| Site boundary | 20 or less | 15 or less | 15 ~20 | 10 ~ 15 |

· Designated odor substance

| Division | Emission acceptance standard (ppm) | | The range of strict emission acceptance standard (ppm) | Application period |
|---|---|---|---|---|
| | Industrial area | Other regions | Industrial area | |
| Ammonia | 2 or less | 1 or less | 1 ~2 | From 2005. 2. 10 |
| Methyl mercaptan | 0.004 or less | 0.002 or less | 0.002 ~ 0.004 | |
| Hydrogen sulfide | 0.06 or less | 0.02 or less | 0.02 ~ 0.06 | |
| Dimethylsulfide | 0.05 or less | 0.01 or less | 0.01 ~ 0.05 | |
| Dimethyl disulfide | 0.03 or less | 0.009 or less | 0.009 ~ 0.03 | |
| Trimethylamine | 0.02 or less | 0.005 or less | 0.005 ~ 0.02 | |
| Acetaldehyde | 0.1 or less | 0.05 or less | 0.05 ~ 0.1 | |
| Styrene | 0.8 or less | 0.4 or less | 0.4 ~ 0.8 | |
| Propionic aldehyde | 0.1 or less | 0.05 or less | 0.05 ~ 0.1 | |
| Butyl aldehyde | 0.1 or less | 0.029 or less | 0.029 ~ 0.1 | |
| n-vale raldehyde | 0.02 or less | 0.009 or less | 0.009 ~ 0.02 | |
| I-vale raldehyde | 0.006 or less | 0.003 or less | 0.003 ~ 0.006 | |
| Toluene | 30 or less | 10 or less | 10 ~ 30 | From 2008. 1. 1 |
| Xylene | 2 or less | 1 or less | 1 ~ 2 | |
| Methyl ethyl ketone | 35 or less | 13 or less | 13 ~ 35 | From 2010.1. 1 |
| Methyl isobutyl ketone | 3 or less | 1 or less | 1 ~ 3 | |
| Butyl acetate | 4 or less | 1 or less | 1 ~ 4 | |
| Propionic acid | 0.07 or less | 0.03 or less | 0.03 ~ 0.07 | |
| n-butylic acid | 0.002 or less | 0.001 or less | 0.001 ~ 0.002 | |
| n-valeric acid | 0.002 or less | 0.0009 or less | 0.0009 ~ 0.002 | |
| I-valeric acid | 0.004 or less | 0.001 or less | 0.001 ~ 0.004 | |
| I-butyl alcohol | 4.0 or less | 0.9 or less | 0.9 ~ 4.0 | |

* Annex 3 of the Enforcenent Rules of the Odor Prevention Act

E & Chem Solution Corp.
Environment, Energy & Chemical Solution

**TEL** +82-031-791-9471 | **FAX** +82-02-6442-3502 | www.enchem.co.kr
94-38, Yongjeong-ro 1-gil, Gunnae-myeon, Pocheon-si, Gyeonggi-do

Environment, Energy and Chemistry

# E&CHEM SOLUTION

Environment Energy & Chemical Solution

## MIRESORB®

Adsorbent for arsenic removal

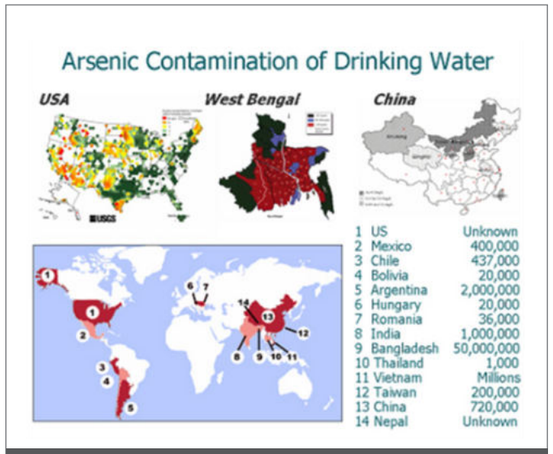
E & Chem Solution Corp.
Environment, Energy & Chemical Solution

## Arsenic (As)

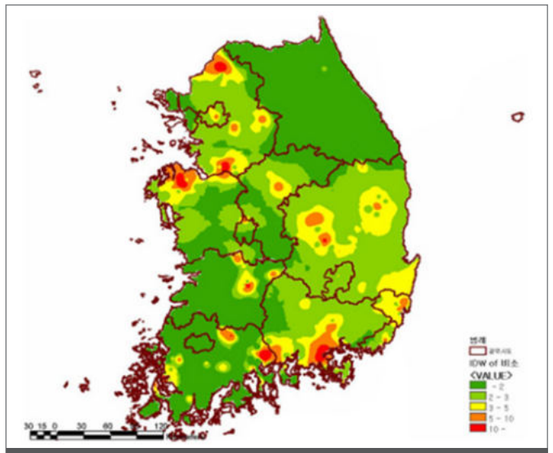
- It is classified as a first-class carcinogen and mainly causes skin and liver cancer.
- It found in elemental conditions but exists mainly as sulfides
- Trivalent arsenic is about 40 to 60 times more toxic than pentavalent arsenic
- It exists in various forms such as Realgar($As_4S_4$), Orpiment($As_2S_3$), Arsenopyrite(FeSAs)

33
As
Arsenic
74.92160(2)
[Ar] $4s^2$ $3d^{10}$ $4p^3$

## Arsenic contamination status of domestic and foreign groundwater




Overseas



Domestic

**Drinking water standards in countries and organizations including WHO and USEPA: 10 µg/L**





## MIRESORB® Overview

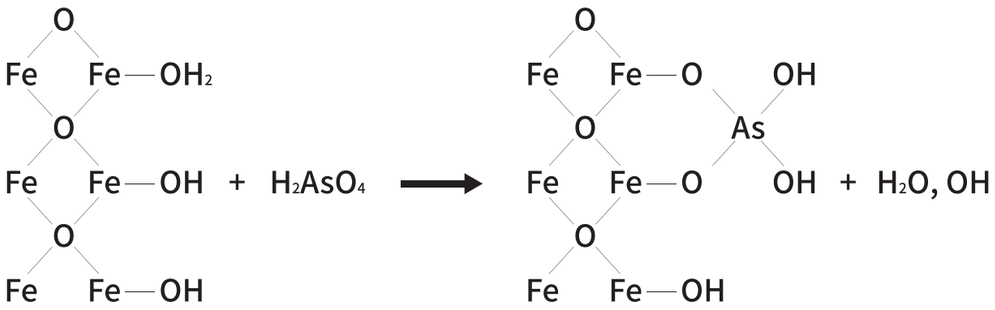
MIRESORB®, an arsenic and heavy metal adsorbent in the water quality of E&C Solution Co., Ltd., is a porous adsorbent manufactured based on iron hydroxide.
MIRESORB® Is a product that guarantees performance through batch characteristics, column tests, on-site pilot test and actual delievery. Compared to foreign products, the performance is equal or higher and the price is 1/2 and the cost performance is very good

Granular type

Pellet type

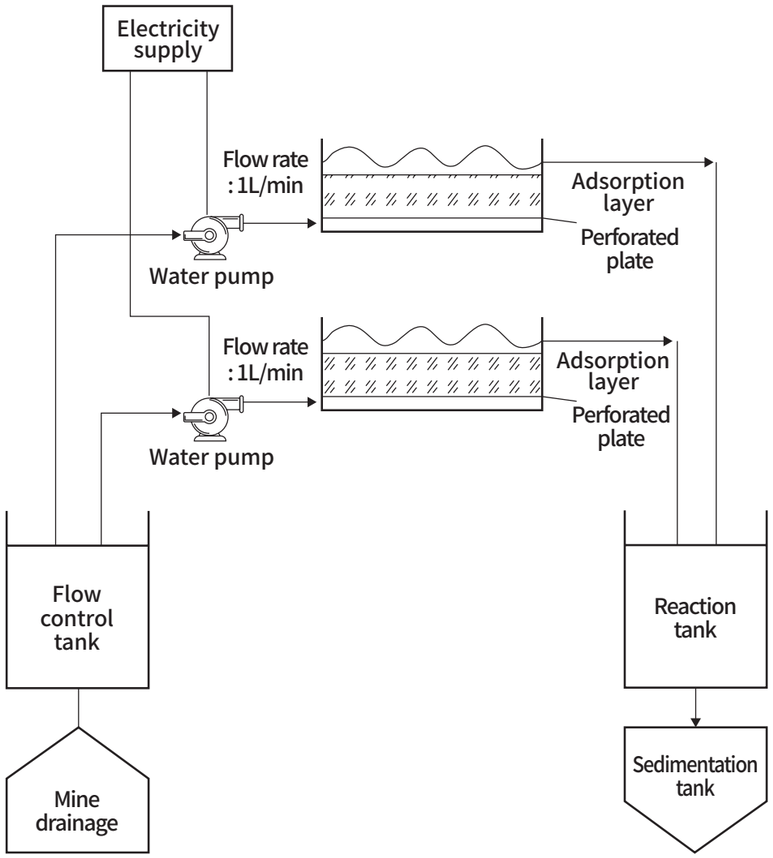
- **As an insoluble inorganic compound, there is no concern about dissolution**
- **Performance assurance available in various EBCTs.**
- **Principal component** : amorphous iron hydroxide($Fe(OH)_3$)
- **Specific surface area** : 200~250$m^2$/g
- **Grain size** : Customization
- **Designable with packing factor**
- **Arsenic (V) adsorption capacity** : 1 wt% or more
- **Adsorption capacity of heavy metals** : 1wt% or more

## MIRESORB® Arsenic Adsorption Principle




<Arsenic adsorption mechanism>

Based on adsorption principle for arsenic removal mechanism using iron hydroxide, arsenic ions are physically adsorbed on the OH-groups of the porous adsorbent.



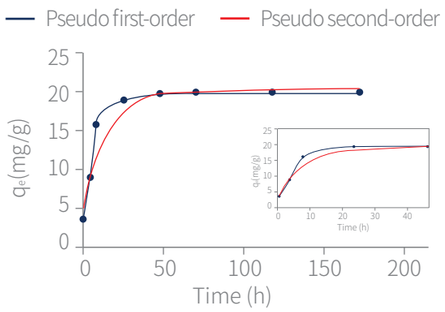

<Pilot-plant PFD for arsenic removal>



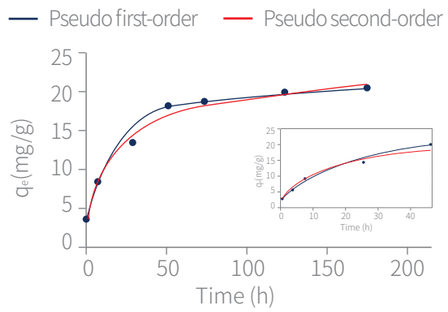
## MIRESORB® arsenic removal and adsorption performance evaluation

### Adsorption kinetics evaluation

**(a) MIRESORB®**



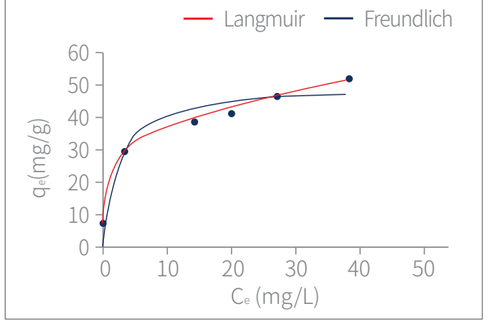

**(b) Competitor**



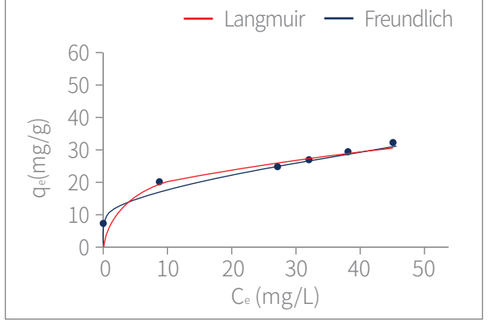

| Adsorbent | Pseudo First-Order | | | Pseudo Second-Order | | |
|---|---|---|---|---|---|---|
| | $q_e$(mg/g) | $K_1$(1/h) | $R^2$ | $q_e$(mg/g) | $K_2$(g/(mg·h)) | $R^2$ |
| MIRESORB™ | 19.76 | 0.227 | 0.990 | 20.88 | 0.015 | 0.958 |
| Competitor | 19.58 | 0.076 | 0.977 | 21.74 | 0.005 | 0.986 |

### Isothermal adsorption evaluation

**(a) MIRESORB®**




**(b) Competitor**



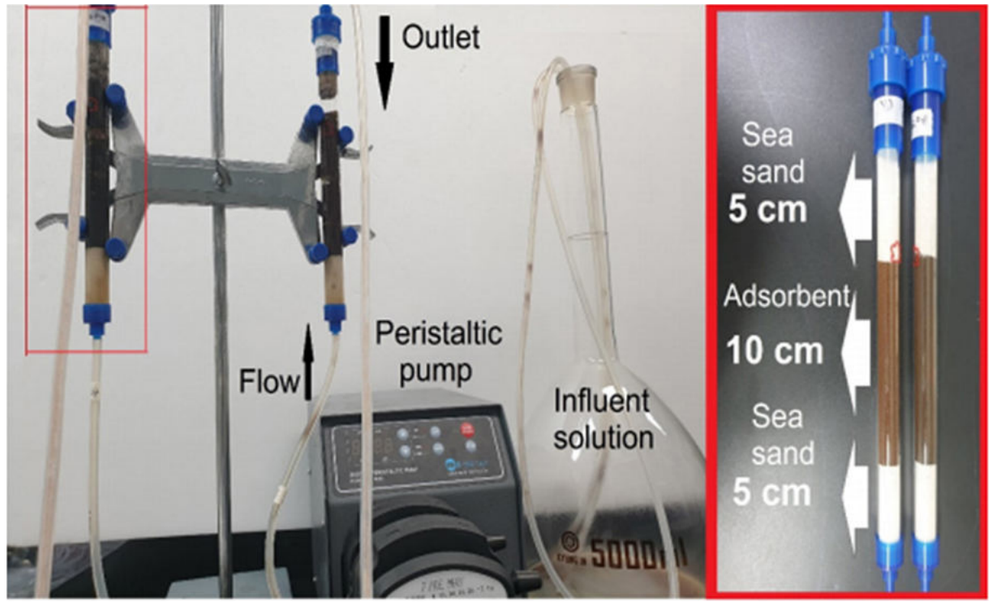

| Adsorbent | Langmuir Isotherm | | | Freundlich Isotherm | | |
|---|---|---|---|---|---|---|
| | $q_m$(mg/g) | $K_L$(L/mg) | $R^2$ | $K_F$ ([mg/g]·[mg/L]$^{1/n}$) | n(1/n) | $R^2$ |
| MIRESORB™ | 50.387 | 0.38 | 0.91 | 19.04 | 3.68(0.27) | 0.98 |
| Competitor | 29.07 | 0.33 | 0.94 | 12.00 | 4.35(0.23) | 0.95 |

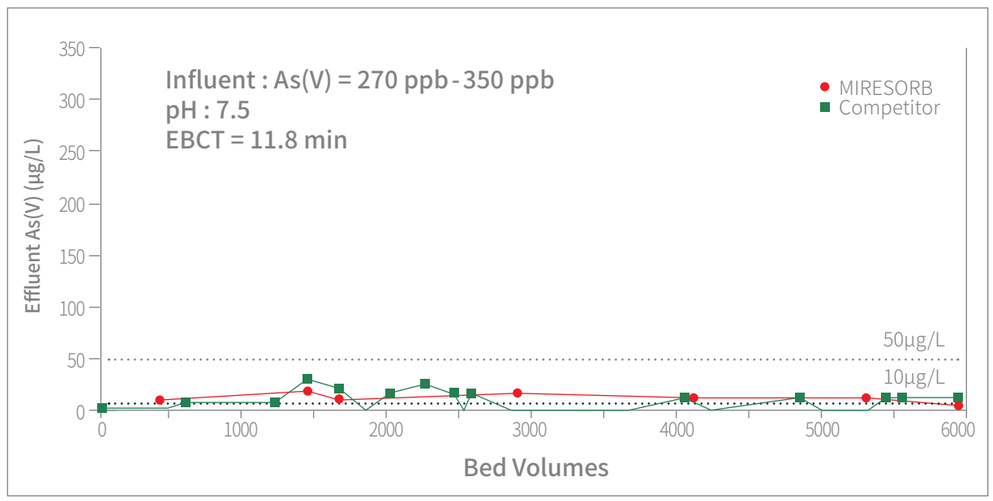
Ref. : **“Arsenic (V) Removal by an Adsorbent Material Derived from Acid Mine Drainage Sludge”**, Applied Sciences(2021) Vol.11, No.1 47



MIRESORB® | Adsprbent for arsenic removal

## MIRESORB® columm test for low concentration arsenic removal

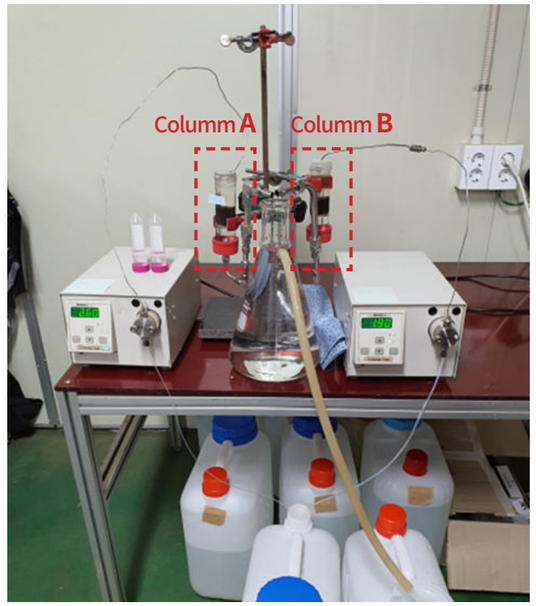



In the case of column experiments using actual mine drainage, adsorption performance is maintained even after 5,800 bed volume is removed.

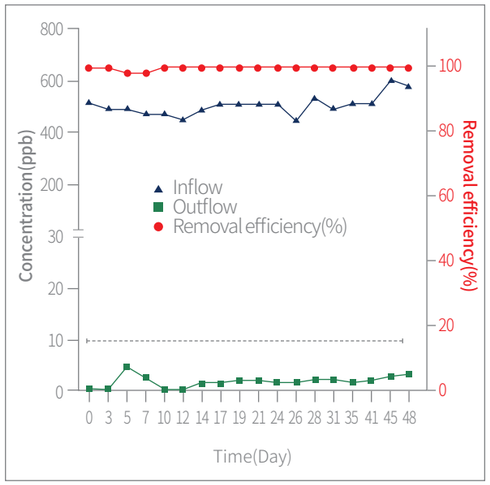
Ref. : **"Arsenic (V) Removal by an Adsorbent Material Derived from Acid Mine Drainage Sludge"**, Applied Sciences(2021) Vol.11, No.1 47

## MIRESORB® columm test for high-concentration arsenic removal

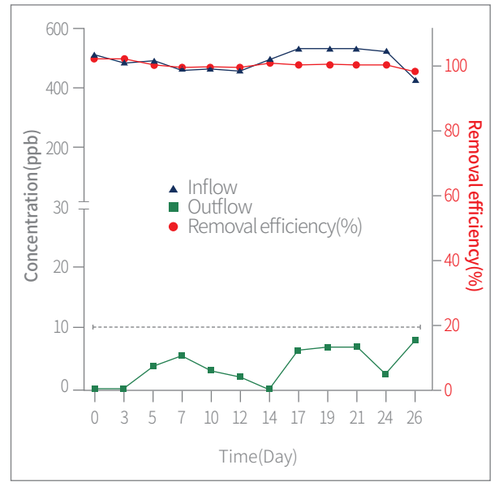



<Lab test using arsenic contaminated water>

As(V) Removal Plot <Columm A>




As(V) Removal Plot <Columm B>




In the case of performance experiments using actual mine drainage, the AS(V) removal rate is maintained at 99% or more for 48 days.
Contaminated water used (Raw water : Mine drainage in area B)
- Arsenic (V) contained : approximately 500 ppb

## MIRESORB® pilot test for low-concentration arsenic and zinc removal

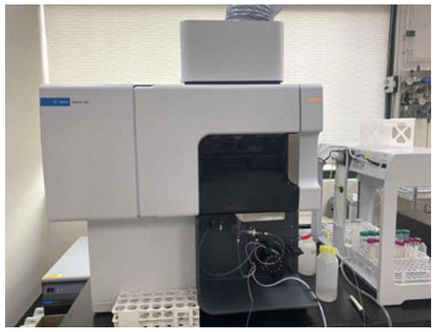
**Inflow raw water condition**

- **Demonstration test capacity** : 100ml/min
- **Arsenic (V) inflow concentration** : 70 ~ 400 mg/L
- **Test bed size** : 90L(Packed, 50L)
- **Raw water inflow method** : Using a metering pump


**Raw water inflow site**


<Examination Point>

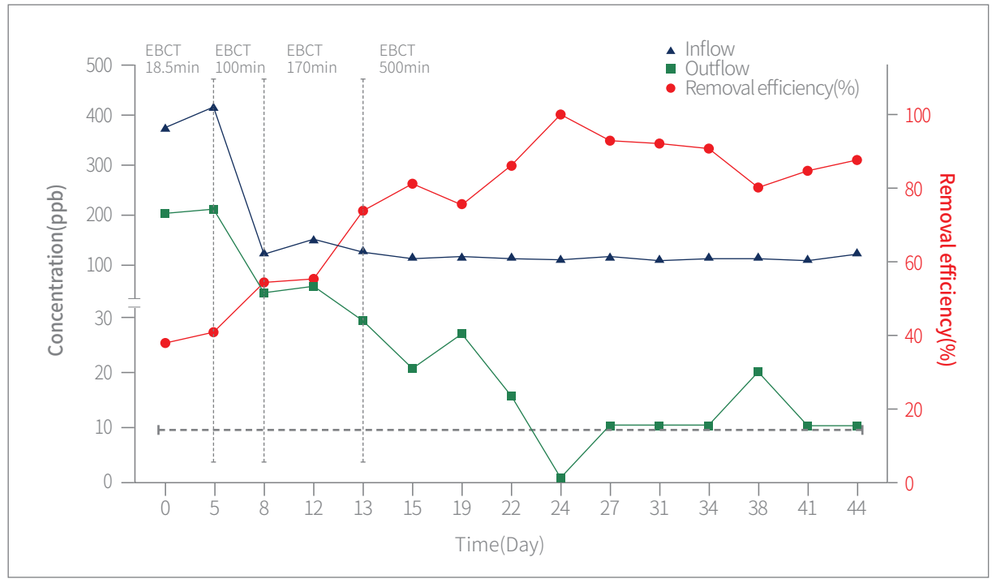
**Installation of demonstration equipment**



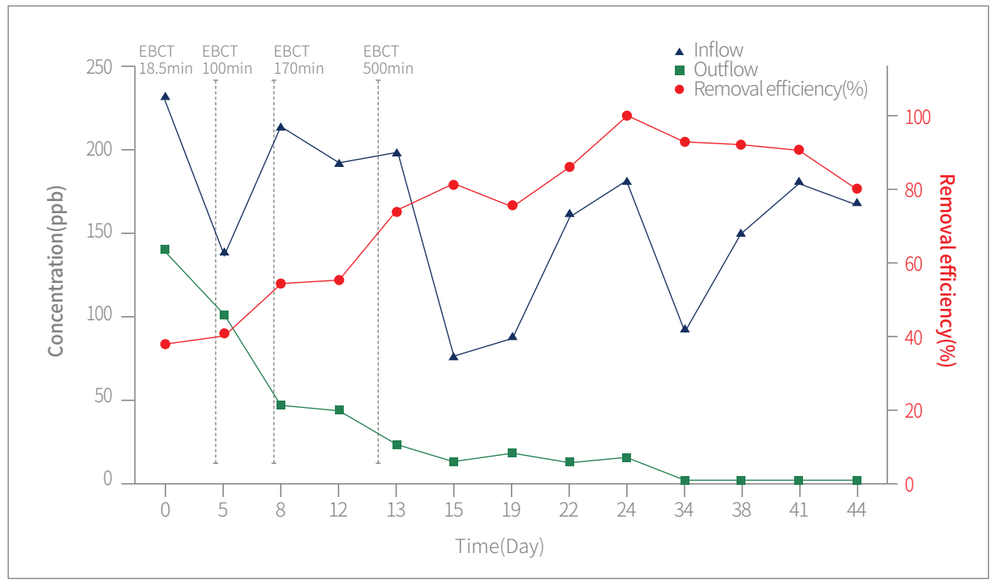
<Arsenic removal efficiency analysis>

ICP-AES, 5110 SVDV, Agilent
microscopic inorganic element analysis

## MIRESORB® pilot-test results for low-concentration arsenic removal and zinc removal




< Removal efficiency of Arsenic (IV) with time(day) in pilot test >




< Removal efficiency of Zinc(II) with time(day) in pilot test >

## MIRESORB® on-site application and delivery site

### ※ Arsenic and Heavy Metal Process in North Gyeongsang abandoned gold mine

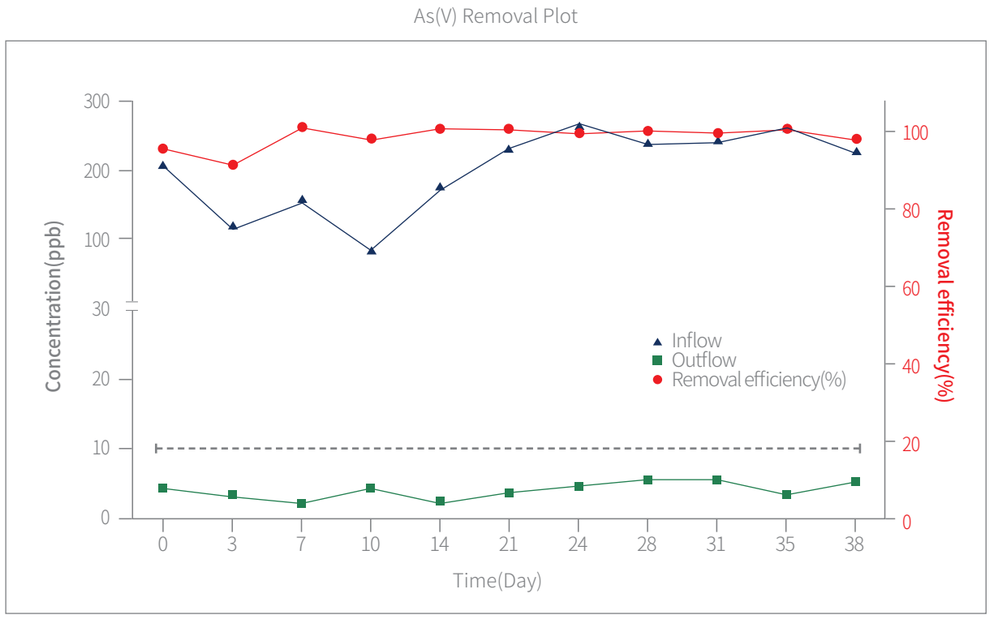
· A system that coarse contaminants in raw water are removed by precipitation in storage tank, and arsenic and other heavy metals are removed by adsorption in adsorption tank, finally being discharged.
· The contaminated water is fed to the storage tank through bottom line by hydrostatic pressure and it comprises several layers such as perforated tube, limestone, arsenic-removing adsorbent and sand from the bottom.



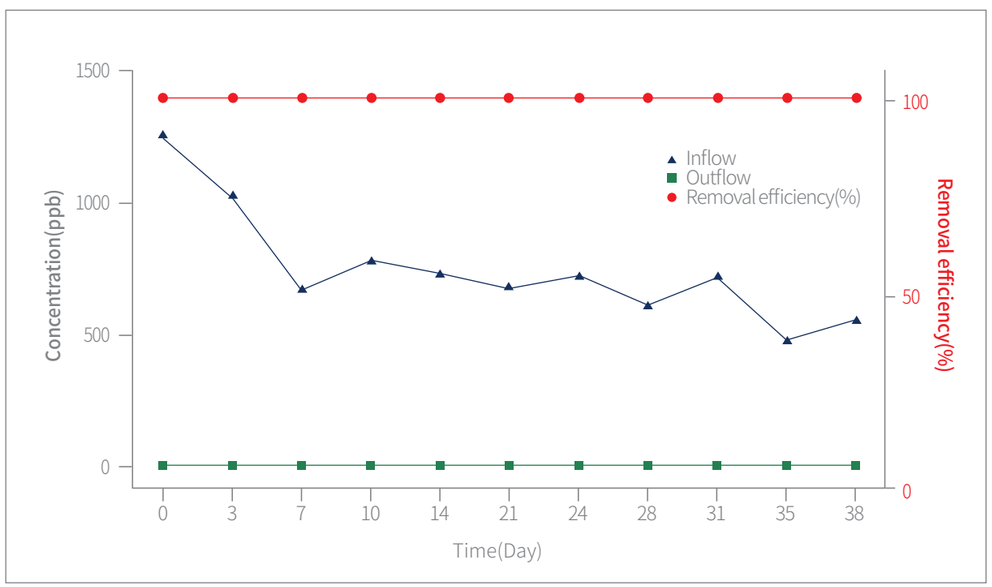



## MIRESORB® results of on-site application test operation

### Arsenic removal efficiency with time(day) for inflow, and resulting outflow concentrations




### Zinc removal efficiency with time(day) for inflow, and resulting outflow concentrations



# Analysis report

## Analytical device - ICP MS

1. Pilot Test Part 7  2. Trial run result Part 7  3. Lab Test Part 5

분석 결과

서울과학기술대학교/ 공동실험실습관/ 화학성분분석실

▶ 분석 날짜 : 2021. 8. 31.

▶ 분석 결과 :

| 원소명 / 시료명 | Ca [ppm] | As [ppm] |
|---|---|---|
| 0816-front | 78.03 | 0.49 |
| 0816-back 초속정 | 39.63 | 0.00 |
| 0818-front | 78.34 | 0.49 |
| 0818-back 일반 | 15.04 | 0.01 |
| 0818-back 초속정 | 55.59 | 0.01 |
| 0820-front | 76.83 | 0.47 |
| 0820-back 일반 | 32.28 | 0.01 |
| 0820-back 초속정 | 58.32 | 0.01 |
| 0823-front | 77.40 | 0.47 |
| 0823-back 일반 | 51.84 | 0.00 |
| 0823-back 초속정 | 61.47 | 0.01 |
| 0825-front | 77.36 | 0.46 |
| 0825-back 일반 | 61.31 | 0.00 |
| 0825-back 초속정 | 66.35 | 0.01 |

※ 이 결과는 학술연구 등의 목적이외에 어떠한 경우에도 법적요건(선전, 광고, 소송 등)으로 이용할 수 없습니다.

▶ 장비 설명 :

| 사용 장비명 | 용도 | 모델 및 제작사 |
|---|---|---|
| 유도결합플라즈마 원자방출분광기 (Inductively coupled plasma atomic emission spectrometer) | 미량 무기원소분석 | Agilent 5110(SVDV) |

서울과학기술대학교 공동실험실습관

Inductively coupled plasma atomic emission spectrometer test report

분석 결과

서울과학기술대학교/ 공동실험실습관/ 화학성분분석실

▶ 분석 날짜 : 2021. 9. 6. ~ 7.

▶ 분석 결과 :

| 원소명 / 시료명 | As [ppb] |
|---|---|
| 8/30 유출 | 1.81 |
| 8/30 유입 | 153.85 |
| 9/2 유출 | 4.05 |
| 9/2 유입 | 92.41 |

※ 이 결과는 학술연구 등의 목적이외에 어떠한 경우에도 법적요건(선전, 광고, 소송 등)으로 이용할 수 없습니다.

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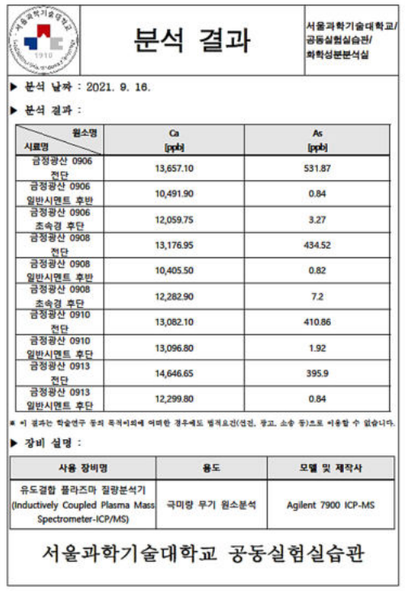
|---|---|---|
| 유도결합 플라즈마 질량분석기 (Inductively Coupled Plasma Mass Spectrometer-ICP/MS) | 극미량 무기 원소분석 | Agilent 7900 ICP-MS |

서울과학기술대학교 공동실험실습관

Inductively coupled plasma mass spectrometer test report



분석 결과

서울과학기술대학교/ 공동실험실습관/ 화학성분분석실

▶ 분석 날짜 : 2021. 9. 16.

▶ 분석 결과 :

| 원소명 / 시료명 | Ca [ppb] | As [ppb] |
|---|---|---|
| 금정광산 0906 전단 | 13,657.10 | 531.87 |
| 금정광산 0906 일반시멘트 후반 | 10,491.90 | 0.84 |
| 금정광산 0906 초속경 후단 | 12,059.75 | 3.27 |
| 금정광산 0908 전단 | 13,176.95 | 434.52 |
| 금정광산 0908 일반시멘트 후반 | 10,405.50 | 0.82 |
| 금정광산 0908 초속경 후단 | 12,282.90 | 7.2 |
| 금정광산 0910 전단 | 13,082.10 | 410.86 |
| 금정광산 0910 일반시멘트 후단 | 13,096.80 | 1.92 |
| 금정광산 0913 전단 | 14,646.65 | 395.9 |
| 금정광산 0913 일반시멘트 후단 | 12,299.80 | 0.84 |

※ 이 결과는 학술연구 등의 목적이외에 어떠한 경우에도 법적요건(선전, 광고, 소송 등)으로 이용할 수 없습니다.

▶ 장비 설명 :

| 사용 장비명 | 용도 | 모델 및 제작사 |
|---|---|---|
| 유도결합 플라즈마 질량분석기 (Inductively Coupled Plasma Mass Spectrometer-ICP/MS) | 극미량 무기 원소분석 | Agilent 7900 ICP-MS |

서울과학기술대학교 공동실험실습관

Inductively coupled plasma mass spectrometer test report

분석 결과

서울과학기술대학교/ 공동실험실습관/ 화학성분분석실

▶ 분석 날짜 : 2021. 8. 17. ~ 18.

▶ 분석 결과 :

| 원소명 / 시료명 | Ca [ppm] | Cd [ppm] | Cr [ppm] | Cu [ppm] | Ni [ppm] | Pb [ppm] | Zn [ppm] | As [ppm] | Hg [ppm] |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | 3.56 | 804.90 | 7.13 | 11.34 | 43.22 | 107,855 | 1.15 | 0 |
| 2 | 89.05 | | | | | | | 2.50 | |

※ 이 결과는 학술연구 등의 목적이외에 어떠한 경우에도 법적요건(선전, 광고, 소송 등)으로 이용할 수 없습니다.

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|---|---|---|
| 유도결합플라즈마 원자방출분광기 (Inductively coupled plasma atomic emission spectrometer) | 미량 무기원소분석 | Agilent 5110(SVDV) |

서울과학기술대학교 공동실험실습관

Inductively coupled plasma atomic emission spectrometer test report



MIRESORB® | Adsprbent for arsenic removal

# Analysis report

분석 결과

서울과학기술대학교/ 공동실험실습관/ 화학성분분석실

▶ 분석 날짜 : 2021. 9. 13.

▶ 분석 결과 :

| 원소명 / 시료명 | As [ppb] |
|---|---|
| 고로석산 9/6 유입 | 158.94 |
| 고로석산 9/6 유출 | 1.80 |
| 고로석산 9/9 유입 | 84.09 |
| 고로석산 9/9 유출 | 71.71 |

※ 이 결과는 학술연구 등의 목적이외에 어떠한 경우에도 법적요건(선전, 광고, 소송 등)으로 이용할 수 없습니다.

▶ 장비 설명 :

| 사용 장비명 | 용도 | 모델 및 제작사 |
|---|---|---|
| 유도결합 플라즈마 질량분석기 (Inductively Coupled Plasma Mass Spectrometer-ICP/MS) | 극미량 무기 원소분석 | Agilent 7900 ICP-MS |

서울과학기술대학교 공동실험실습관

Inductively coupled plasma mass spectrometer test report

분석 결과

서울과학기술대학교/ 공동실험실습관/ 화학성분분석실

▶ 분석 날짜 : 2021. 9. 23.

▶ 분석 결과 :

| 원소명 / 시료명 | Zn [ppb] |
|---|---|
| 고로석산 9/13 유입 | 665.40 |
| 고로석산 9/13 유출 | 0 |
| 고로석산 9/16 유입 | 700.04 |
| 고로석산 9/16 유출 | 0 |

※ 이 결과는 학술연구 등의 목적이외에 어떠한 경우에도 법적요건(선전, 광고, 소송 등)으로 이용할 수 없습니다.

▶ 장비 설명 :

| 사용 장비명 | 용도 | 모델 및 제작사 |
|---|---|---|
| 유도결합 플라즈마 질량분석기 (Inductively Coupled Plasma Mass Spectrometer-ICP/MS) | 극미량 무기 원소분석 | Agilent 7900 ICP-MS |

서울과학기술대학교 공동실험실습관

Inductively coupled plasma mass spectrometer test report

분석 결과

서울과학기술대학교/ 공동실험실습관/ 화학성분분석실

▶ 분석 날짜 : 2021. 9. 23.

▶ 분석 결과 :

| 원소명 / 시료명 | As [ppb] |
|---|---|
| 고로석산 9/13 유입 | 220.25 |
| 고로석산 9/13 유출 | 2.63 |
| 고로석산 9/16 유입 | 246.76 |
| 고로석산 9/16 유출 | 4.22 |

※ 이 결과는 학술연구 등의 목적이외에 어떠한 경우에도 법적요건(선전, 광고, 소송 등)으로 이용할 수 없습니다.

▶ 장비 설명 :

| 사용 장비명 | 용도 | 모델 및 제작사 |
|---|---|---|
| 유도결합 플라즈마 질량분석기 (Inductively Coupled Plasma Mass Spectrometer-ICP/MS) | 극미량 무기 원소분석 | Agilent 7900 ICP-MS |

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▶ 분석 날짜 : 2021. 9. 13.

▶ 분석 결과 :

| 원소명 / 시료명 | Zn [ppb] |
|---|---|
| 고로석산 9/6 유입 | 706.82 |
| 고로석산 9/6 유출 | 0 |
| 고로석산 9/9 유입 | 394.13 |
| 고로석산 9/9 유출 | 162.55 |

※ 이 결과는 학술연구 등의 목적이외에 어떠한 경우에도 법적요건(선전, 광고, 소송 등)으로 이용할 수 없습니다.

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Inductively coupled plasma mass spectrometer test report

Environment, Energy and Chemistry

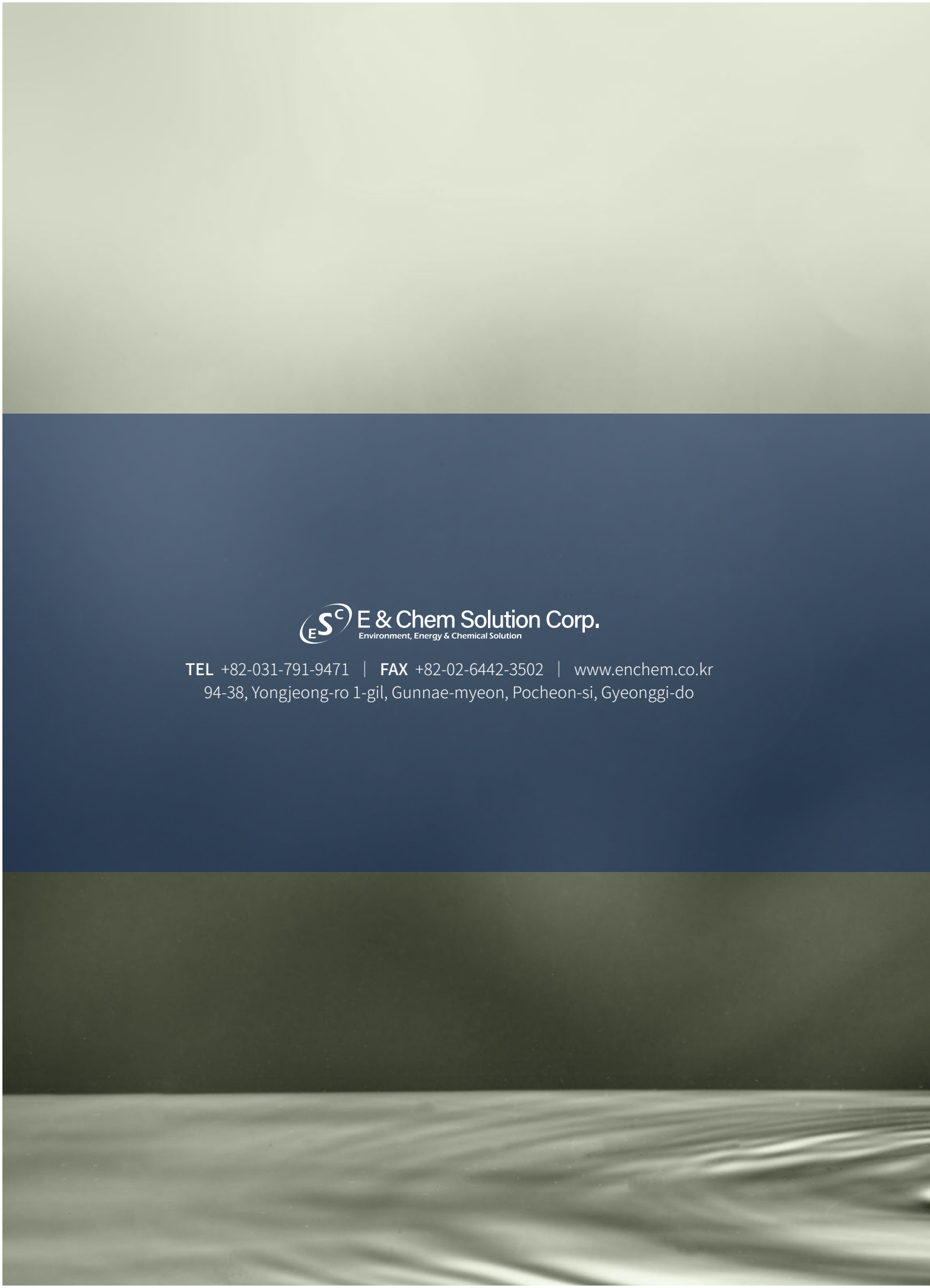
# E&CHEM SOLUTION

Environment Energy & Chemical Solution



E & Chem Solution Corp.
Environment, Energy & Chemical Solution

MIRESORB® | Adsprbent for arsenic removal



E & Chem Solution Corp.
Environment, Energy & Chemical Solution

**TEL** +82-031-791-9471 | **FAX** +82-02-6442-3502 | www.enchem.co.kr
94-38, Yongjeong-ro 1-gil, Gunnae-myeon, Pocheon-si, Gyeonggi-do

Environment, Energy and Chemistry

# E&CHEM SOLUTION

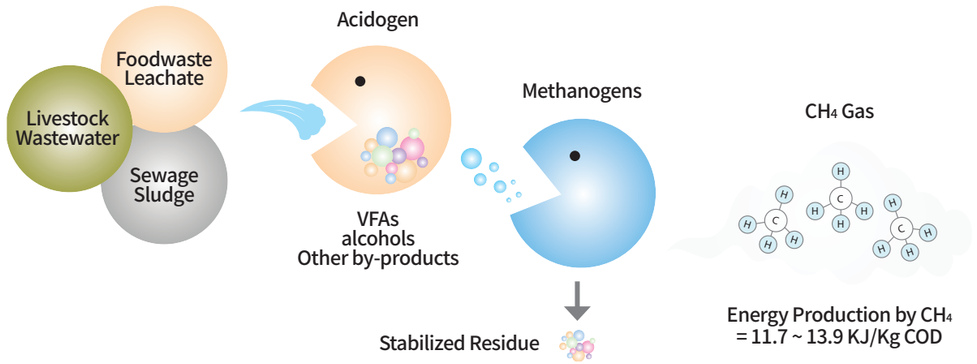
Environment Energy & Chemical Solution

## DSULFER ®

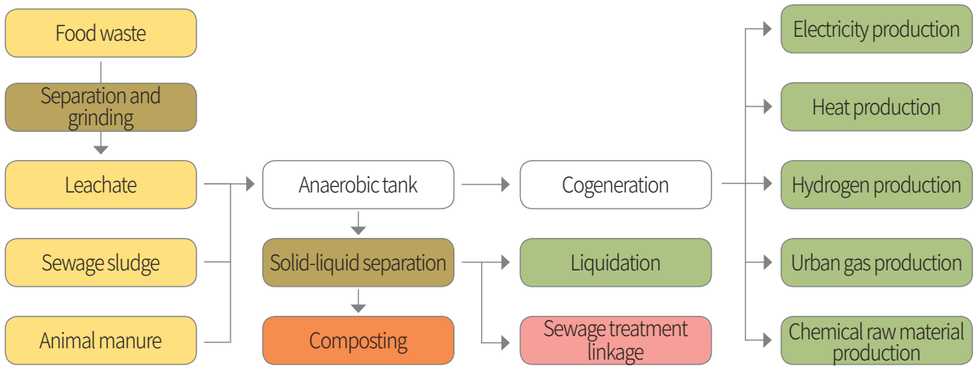
Iron hydroxide stabilizer for inhibiting
hydrogen sulfide production in a digester

E & Chem Solution Corp.
Environment, Energy & Chemical Solution

## Biogasification




## Basic biogas plant process



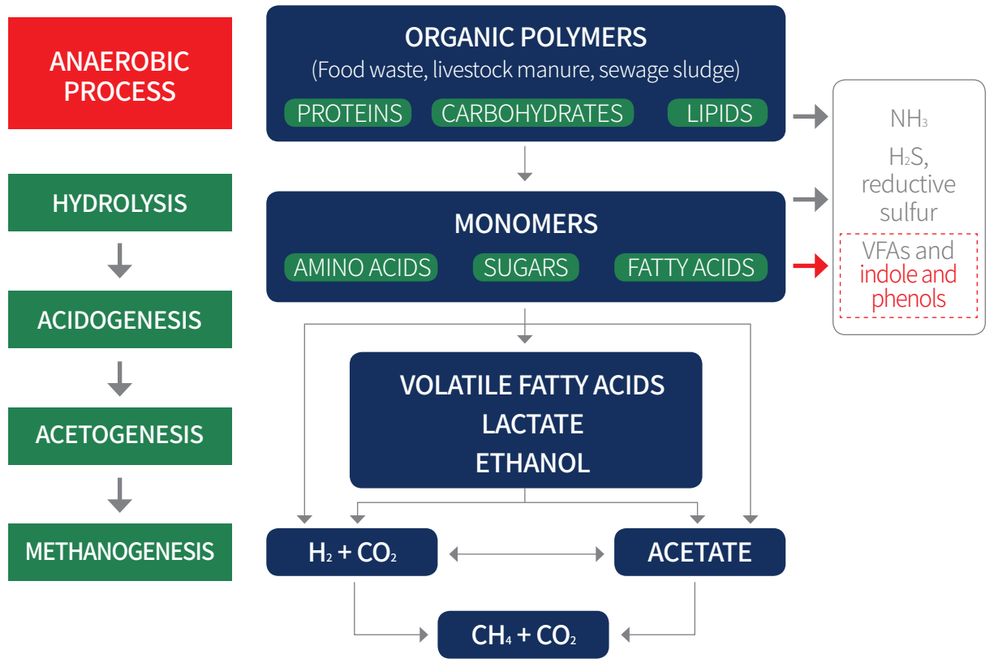

| Reaction process | Reaction formula | Microorganism |
|---|---|---|
| Hydrolysis stage | Organic substances → Sugars, Glycerin, Fatty acids, Amino acids | Microbial in vitro enzyme |
| Acid production stage | Sugar → Acetic acid, Propionic acid, Butyric acid | Organic acid-producing bacteria |
| Methane production stage | $CH_3COOH + 2H_2O \rightarrow 2CO_2 + 8H$ (Oxidation reaction)<br>$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$ (Reduction reaction) | Methane microorganism |
| Hydrogen sulfide production stage | $SO_4^{2-}$ + organic matter → $S^{2-} + CO_2$<br>$S^{2-} + 2H^+ \rightarrow H_2S$ | Sulphur-reducing bacteria (SRB) |

## Iron hydroxide-iron chloride hydrogen sulfide reaction formula

- $2Fe(OH)_3 + 3HS^- + 3H^+ \rightarrow 2FeS + S + 6H_2O$
- $2Fe(OH)_3 + 3HS^- + 3H^+ \rightarrow Fe_2S_3 + 6H_2O$
- $2Fe(OH)_3 + 3H_2S \rightarrow 2FeS + S + 6H_2O$
- $2Fe(OH)_3 + 3H_2S \rightarrow Fe_2S_3 + 6H_2O$



## By-product from anaerobic digestion process




Hazardous substances that inhibit anaerobic digestion are free ammonia, free hydrogen sulfide, heavy metals, etc., and ammonia toxicity occurs most frequently.

### Hazardous substances caused by anaerobic digestion process

| | |
|---|---|
| **Ammonia** | Produced by deamination reactions during protein degradation in anaerobic reactor<br>Toxicity above $NH_3$ 80 mg/L, $NH_4^+$ 1,500 mg/L |
| **Sulfide** | Less than 20 mg/L is required for optimal methane activity, but decreases if $H_2S$ is 50 to 250 mg/L |
| **Volatile acid** | High concentration pH decreases, inhibition of reaction above 1,000 mg/L of propionic acid |
| **Soluble sulfur compound** | Maximum non-toxic concentration : 200 mg/L<br>Heavy metals such as copper, zinc, and nickel are toxic even at low concentrations. when there is sulfide ($H_2S$ gas, $HS^-$, precipitated sulfur compounds), it is partially precipitated |
| **Antibiotic substance** | Antibiotics, cleaning agents, etc. contained in livestock manure |



DSULFER® | Iron hydroxide stabilizer for inhibiting hydrogen sulfide production in a digester

## Digestive stabilizer (DSULFER®) features of E&Chem Solution Corp.

### Prevention of corrosion damage

Corrosion can be prevented by using DSULFER® to prevent corrosion casused by the spread of sulfuric acid particles by the air supplied during the desulfurization process.

### Handling stability

Iron Hydroxide is a non-toxic material and it can be easily handled with simple equipment and it doesn't deteriorate by mixing the water and doesn't require expensive weighting equipment. so it can protect the entire plant from corrosion damage and makes it to use easily without any training or special equipment

### Explosion Prevention by mixing

When air is injected for desulfurization and mixed with methane, there is a risk of explosion caused by unintended air inflow but the DSULFER® is very safe.

### Convenience of measurement

DSULFER® is excellent in biological stability because it is precipitated by combining with sulfur ions generated in a digester, etc., and it is fully activated a few days after injection. so hydrogen sulfide production is inhibited by the concentration of sulfur contained in the substrate.

### Clean, by-product-free and easy handling

DSULFER® can be supplied in a powdery tone bag or sludge state. so it is very easy to use measure because it supplies a digester in conjuction with organic material in the most biogas plant processes

### Load reduction of desulfurization equipment

DSULFER® can efficiently remove most sulfur ions from the initial digester. Therefore, expensive equipment isn't required for concentration load in the post-sulfur process. so cost can be reduced.



## Comparison of E&Chem Solution Corp. digestive stabilizers

The digestive stabilizer (DSULFER®) is a principle that inhibits the generation of hydrogen sulfide by precipitating the sulfur ions generated by sulfur reducing bacteria (SRB) during the digestion process by microorganisms in the anaerobic digester easily reacting with amorphous iron hydroxide. For this purpose, it is used in an intermediate storage tank, acid fermentation tank or digester.

Unlike other additives, the digester stabilizer (DSULFER®) has an excellent effect in suppressing the generation of hydrogen sulfide because it is added together with the hydrogen sulfide contained in biogas. And the additionally included divalent trace metal has the effect of enhancing the activity of microorganisms.

In addition, unlike other companies' products, it has very good effects in harmful substances, corrosiveness, handling and storability.

**Comparison of properties by additive**

| - | E&Chem Solution Corp. | Iron chloride | Iron oxide |
|---|---|---|---|
| Harmful substance | Very good | Heavy metals, chlorine ions | Good |
| Harmful by-product | None | Heavy metal | None |
| Causticity | Very good | Very bad | Good |
| Sludge generation | Middle | Middle | A lot |
| Handleability | Very good | Very danger | Good |
| Methane concentration | Very good | Very good | Good |
| Digester biocompatibility | Very good | Faulty | Good |
| Removal efficiency | Very good | Very good | Good |
| Risk of explosion | Very good | Very good | Very good |
| Reaction velocity | Good | Very good | Faulty |
| Storability | Good | Danger | Good |



DSULFER® | Iron hydroxide stabilizer for inhibiting hydrogen sulfide production in a digester

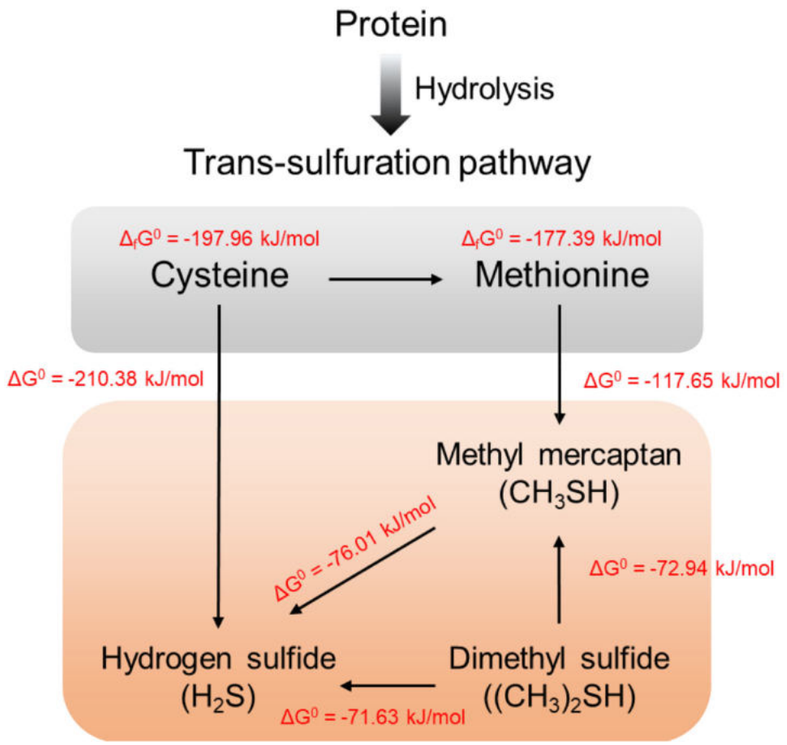
## Ingredient table

Digestive stabilizer (DSULFER®) is a product with high purity through a strictly controlled production process. and it provides excellent hydrogen sulfide production inhibition performance and safety in the digestier.

| Particulars | | | | | |
|---|---|---|---|---|---|
| Ingredient | Iron(lll) hydroxide | | | | |
| Configuration | $Fe(OH)_3$ | | | | |
| Appearance | Reddish brown powder or sludge | | | | |
| Physical property | Item | Maximum value | Minimum value | | |
| | Weight ratio of iron to dry ingredients [wt%] | 60 | 40 | | |
| | Weight ratio of iron hydroxide to dry ingredients [wt%] | 95 | 75 | | |
| | Bulk density [g/cm³] | 0.8 | 1.2 | | |
| | Water content [%] | 10 | 5 | | |
| Trace element content | Kind | Content (mg/kg) | Elution | Verification method | Fertilizer law standard (mg/kg) |
| | This product complies with the guidelines of the Enforcement Decree of the Comparative Management Act [Attachment 1] (Article 10, Paragraph 1). | | | | |
| | Arsenic | 0 | ND* | atomic spectroscopy / process test method | 5 |
| | Cadmium | 0 | ND | | 0.5 |
| | Mercury | 0 | ND | | 0.2 |
| | Lead | 0 | ND | | 15 |
| | Chromium | 0 | ND | | 30 |
| | Copper | -* | ND | | 50 |
| | Zinc | - | ND | | 130 |
| | Nickel | 0 | | | 5 |

* ND: Within the criteria, -: Need to be tested for livestock manure fermentation fluid

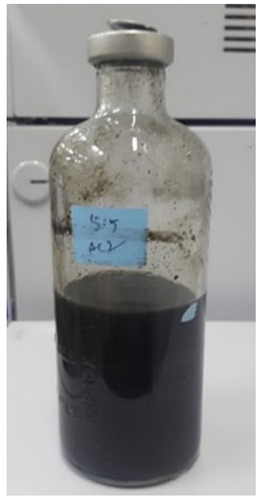
## BMP(Biochemical methane potential) Test




Sulfur-containing gas

**Conditions for testing**

- **Operation type** : Batch
  (Anaerobic digester at city D Sewage Process Plant)
- **Test capacity per batch** : 150ml
- **Concentration of injection of digestive stabilizer**
  : 0g, 0.1g, 0.2g, 0.5g, 1.0g
- **Microbial concentration** : 20.4± 0.1 g VS/L
- **Concentration of organic matter (COD)** :
  5.0g TCOD/L
- **Sulfur concentration** : 20.0 mg/L
- **Digester temperature** : 37 ± 1°C
- **pH** : 7.5
  (Experiments with alkalinity of 5 g/L as $CaCO_3$)
- **Medium** : BA medium

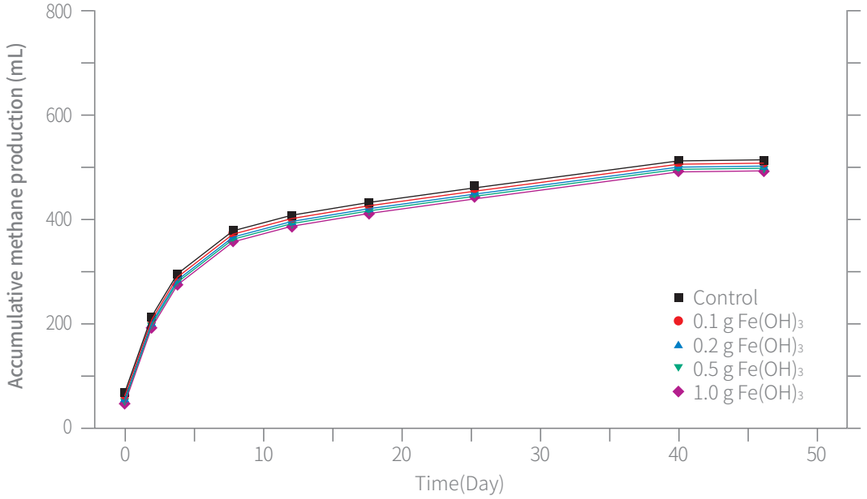






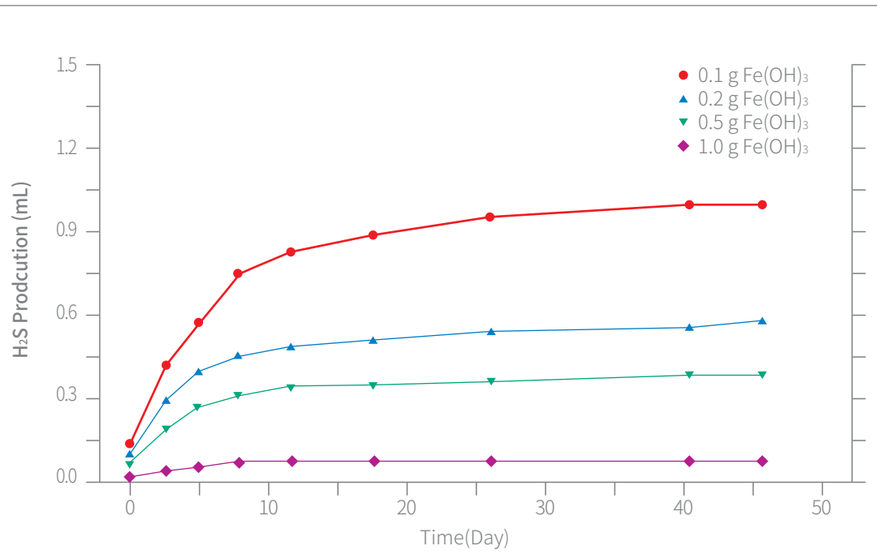
DSULFER® | Iron hydroxide stabilizer for inhibiting hydrogen sulfide production in a digester

## Methane production by concentration of digestive stabilizers



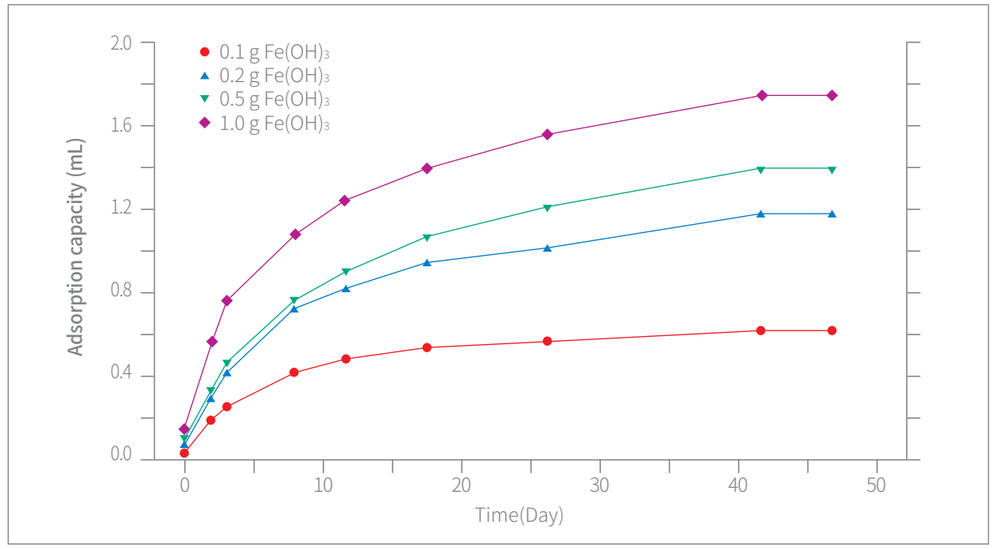

It was confirmed that there was no effect of methane production due to $Fe(OH)_3$ input

## Hydrogen sulfide production by the concentration of digestive stabilizers



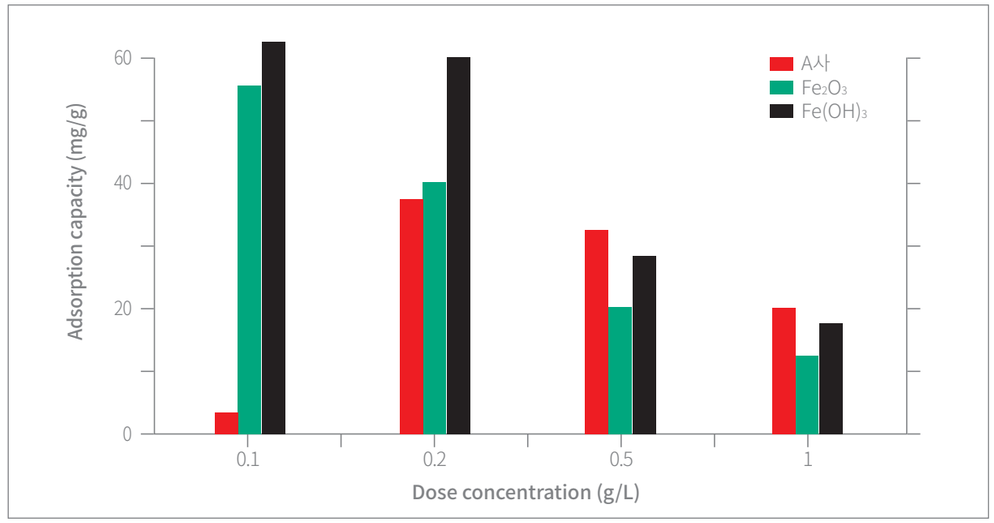

It was confirmed that as the amount of $Fe(OH)_3$ input increases, the amount of hydogen sulfide produced in digester is suppressed.

## Hydrogen sulfide adsorption test of digestive stabilizer




| Dosing amount | Adsorption capacity (mg/g) |
|---|---|
| 0.1 g/L $Fe(OH)_3$ | 63.4 |
| 0.2 g/L $Fe(OH)_3$ | 60.7 |
| 0.5 g/L $Fe(OH)_3$ | 28.4 |
| 1.0 g/L $Fe(OH)_3$ | 17.4 |

## Comparative testing of hydrogen sulfide adsorption capacity of digestive stabilizers




As a result of the experiment of evaluating the adsorption capacity of hydrogen sulfide through BMP tests, it was confirmed that $Fe(OH)_3$ had the highest adsorption amount of hydrogen sulfide per unit mass.

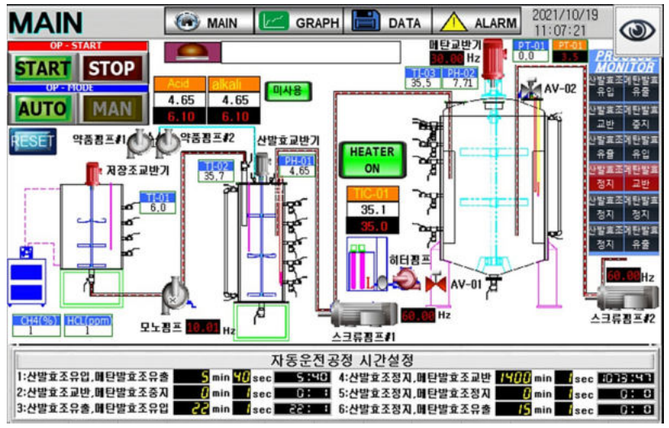




DSULFER® | Iron hydroxide stabilizer for inhibiting hydrogen sulfide production in a digester

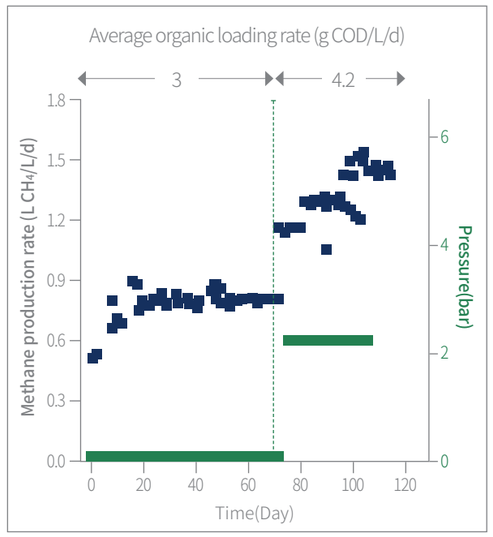
## Anaerobic digestive tank demonstration operation

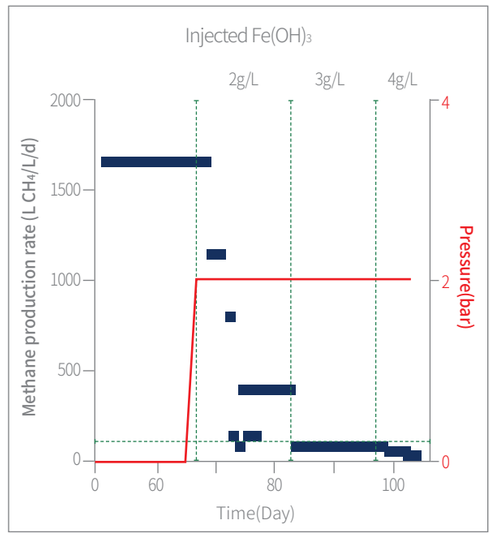
Long-term operation through pilot equipment and remote control




Fire extinguisher capacity: 2,000L

## Empirical test results



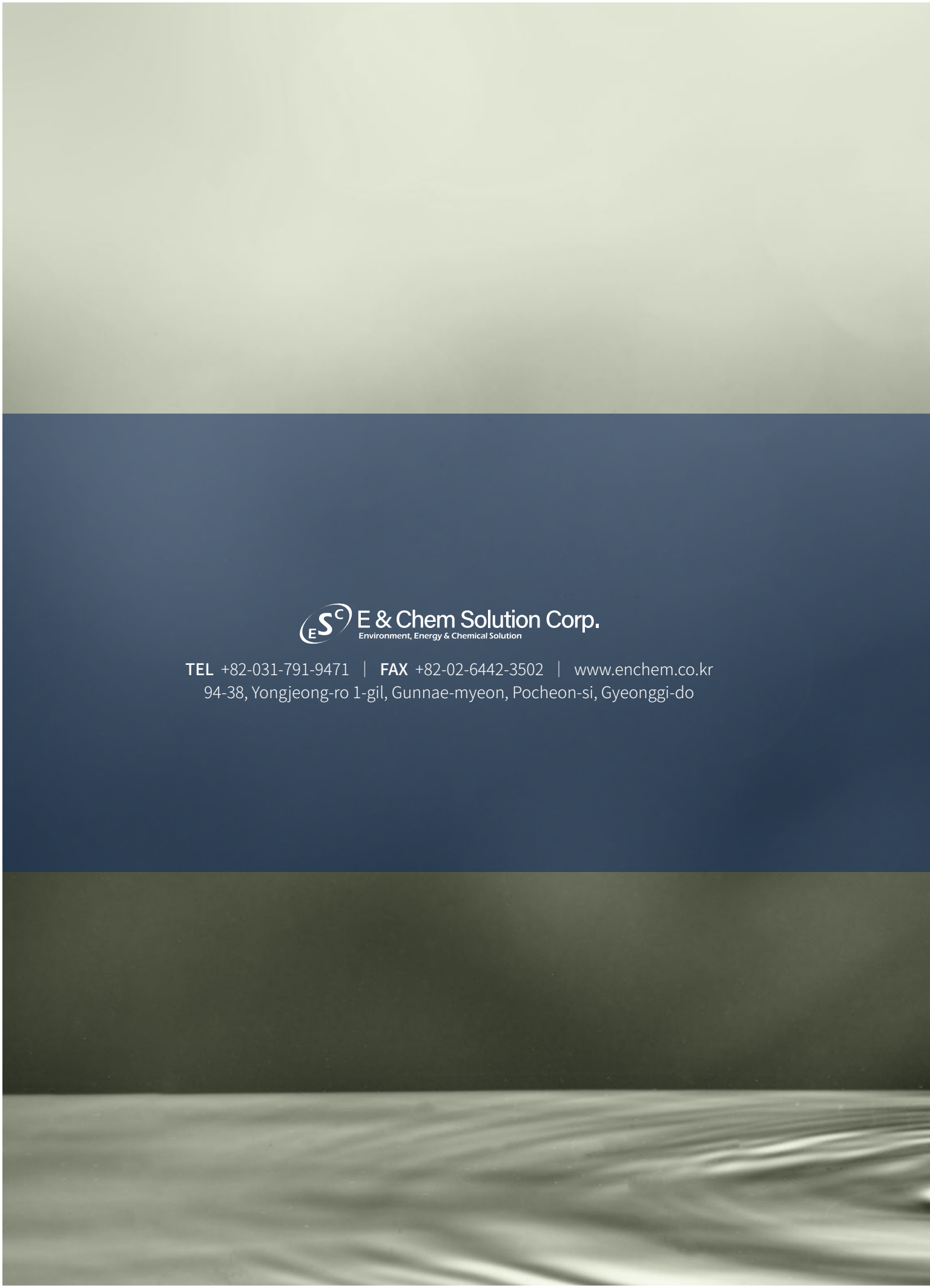




- **Methane production rate** : 1.47 ± 1.2 L/L/d
- **Hydrogen sulfide concentration** : < 90 ppm(Condition: Pressure 2 bar, iron oxide 4g/L)

## Memo



DSULFER® | Iron hydroxide stabilizer for inhibiting hydrogen sulfide production in a digester



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