

## Water pollution prevention technology

### □ Electrochemical treatment

Electrochemical technologies are a promising alternative for the treatment of wastewaters containing organic pollutants. The main advantages of these processes include environmental compatibility, versatility, energy efficiency, safety, selectivity and cost effectiveness. Therefore electrochemical treatment is very efficient and reduces process detention times thereby allowing smaller plants.

The effectiveness of the electrochemical approaches depends strongly on electrode materials and cell parameters (current density, water composition, etc.). Different types of electrodes for indirect electrochemical oxidation have been investigated by various researchers for the treatment of various industrial wastewaters. An electrochemical oxidation process is influenced strongly by the nature of the anode material. Then, the use of high performance anodic materials can achieve high treatment efficiency and lower the operating cost.

From the viewpoint of high efficiency and low resource consumption, electrochemical technologies can be used either as a pretreatment step to increase the biodegradability of a pollutant or as an advanced treatment method further to reduce COD or color in the water to achieve relevant effluent standards. Electrochemical treatment has shown to lower the Biochemical oxygen demand (BOD), chemical oxygen demand (COD), and nitrogen concentration.

Electrochemical treatment are classified with respect to the electrode material, used chemicals and the pollutant removal mechanism. Well known electrochemical treatment are electro-oxidation process(using stable electrodes such as  $\text{PbO}_2$ , mixed metal oxides(MMO) and  $\text{RuO}_2$ ), electro-Fenton process, and peroxi-coagulation process (using  $\text{H}_2\text{O}_2$  as an activator).

Electrochemical oxidation is considered to be a very powerful tool for breaking up even the most resistant organic compounds(non-biodegradable organics). Anodic oxidation of organic contaminants can be performed in several different ways, including both direct and indirect oxidation.

Electrochemical oxidation is a process in which the pollutants are destroyed or converted into simpler forms like carbon dioxide and water. This oxidation process can be either direct or indirect oxidation. In the direct oxidation process, pollutants are adsorbed by the surface of the anode at first, and then through the electron transfer reaction of hydroxyl radical formation ( $\cdot\text{OH}$ ); strong oxidative free radical(active oxygen) damage of pollutant molecular structure, decomposition to  $\text{CO}_2$ . However, competitive reaction of oxygen evolution exists for this process consume part of free radical, reduce the oxidation efficiency. Therefore, the development of high oxygen evolution potential of the electrode is the main way to improve the efficiency. However, competitive reaction of oxygen evolution exists for this process consume part of free radical, reduce the oxidation efficiency. Therefore, the development of high oxygen evolution potential of the electrode is the main way to improve the efficiency. In the indirect oxidation process, strong oxidants like hypochlorite, chlorine, hydrogen peroxide, and hydroxyl ions are electrochemically generated at the anode. The oxidant will be generated and used all of it momentarily. Shortcoming of the chlorine oxidation method is concerns in the electrolytic process may produce organic chlorides increase the toxicity of the wastewater. The hydrogen peroxide( $\text{H}_2\text{O}_2$ ) the advantages of easy to store, transported and its safety procedure process with high efficient, it is widely used as an oxidative agent.

#### ▷ Direct anodic oxidation

In direct anodic oxidation(or direct electron transfer to the anode), the pollutants are destroyed after adsorption on the anode surface, without the involvement of any substances other than the electron. Such oxidation is theoretically possible at more negative potentials than those needed for water splitting and oxygen evolution. However, this process usually results in electrode fouling due to the formation of polymeric layers on its surface and consequently leads to very poor chemical decontamination.

Direct oxidation follows two approaches:

- 1) Direct anodic oxidation (direct electron transfer to the anode), which yields very poor decontamination.
- 2) Chemical reaction with electrogenerated species from water discharge at the anode such as physically adsorbed "active oxygen(hydroxyl radical ( $\cdot\text{OH}$ ))" or chemisorbed "active oxygen(oxygen in the lattice of a metal oxide (MO) anode)". The action of these oxidizing species leads to total or partial decontamination, respectively.

#### ▷ Indirect anodic oxidation

To avoid the deactivation of the anode during direct oxidation of chemicals, an alternative approach is indirect oxidation by destroying pollutants through the electrochemical generation of chemical reactants such as active chlorine, ozone, persulphate, and hydrogen peroxide. The existence of indirect oxidation with different oxidant species has allowed the proposal of new alternatives for the pollution abatement in wastewaters. To avoid the drawbacks of direct oxidation, the indirect oxidation method based on the oxygen evolution region can be used, which has an advantage over direct electrolysis in that it does not need addition of oxidation catalysts to the solution, and it does not produce by-products.

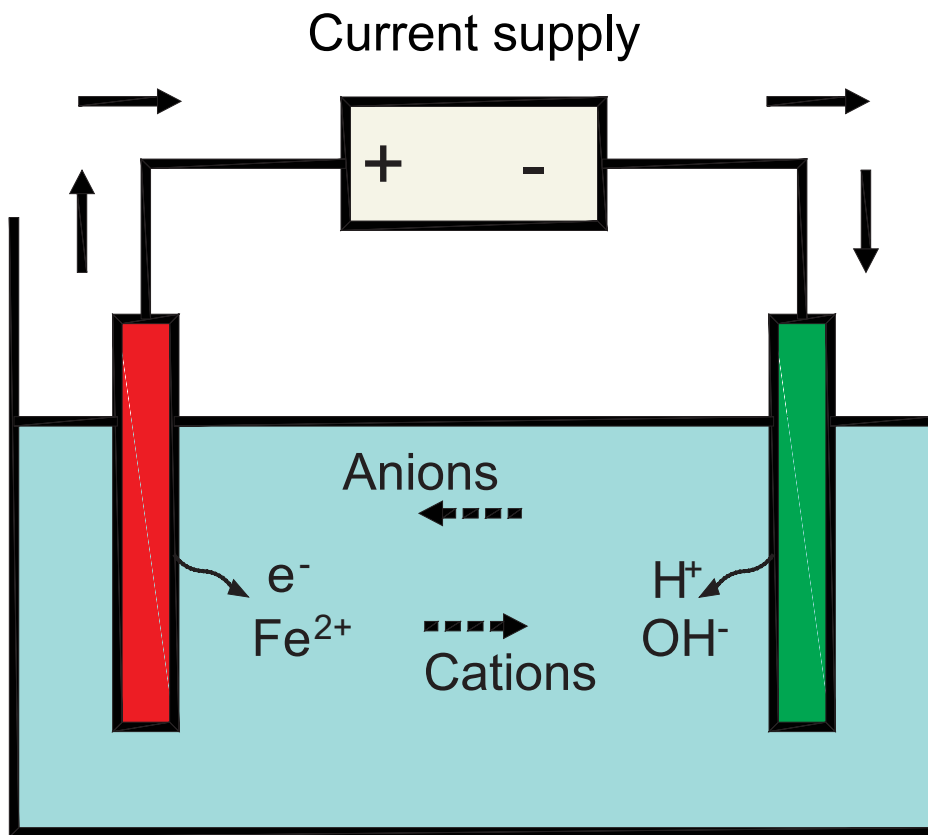
In this process, the electrochemical reaction leads to partial or total decontamination of the electrogenerated species at the anode due to physically adsorbed "active oxygen" (adsorbed hydroxyl radicals  $\cdot\text{OH}$ ) or chemisorbed "active oxygen" (oxygen in the lattice of a metal oxide (MO) anode). This physisorbed  $\cdot\text{OH}$  is the second strongest oxidant known after fluorine, with a high standard potential ( $E_0 = 2.80\text{ V vs. SHE}$ ) that ensures the complete combustion of organic compounds, and the chemisorbed "active oxygen" participates in the formation of selective oxidation products.

The nature of the anode material influences not only the efficiency of the process, but also the electrode selectivity. For example, "active anodes" with low oxygen evolution over potentials such as  $\text{IrO}_2$ ,  $\text{RuO}_2$  or Pt favor the partial and selective oxidation of pollutants, while "non-active anodes" with high oxygen evolution overpotentials such as  $\text{SnO}_2$ ,  $\text{PbO}_2$  or boron-doped diamond (BDD) can facilitate complete combustion, and thus they are regarded as ideal electrodes for the complete oxidation of organics to  $\text{CO}_2$  in wastewater treatment.

Indirect oxidation involving the homogeneous reaction of organic pollutants with strong oxidants generated during electrolysis :

- 1) The electro-oxidation with active chlorine, where direct anodic oxidation of chloride ion present in the effluent leads to the formation of free chlorine and/or chlorine-oxygen species that can oxidize organic pollutants in the bulk.
- 2) The electro-Fenton process in which organics can be mineralized with homogeneous  $\cdot\text{OH}$  formed from Fenton's reaction between added catalytic  $\text{Fe}^{2+}$  and  $\text{H}_2\text{O}_2$  electrogenerated from  $\text{O}_2$  reduction at a suitable cathode.

For case of indirect electrochemical oxidation, pollutants are also competitively destroyed by direct anodic oxidation and by reaction with heterogeneous  $\cdot\text{OH}$  and other reactive oxygen species and weaker oxidants produced from anodic oxidation of water and anions of the electrolyte.



## Water pollution prevention technology

### □ Microbubble flotation technology

Dissolved Air flotation(DAF) is a kind of commonly used solid-liquid separation process in the wastewater treatment, which can effectively remove suspended solids, such as total suspended solids(TSS), fats, oil & grease and other pollutants in the wastewater.

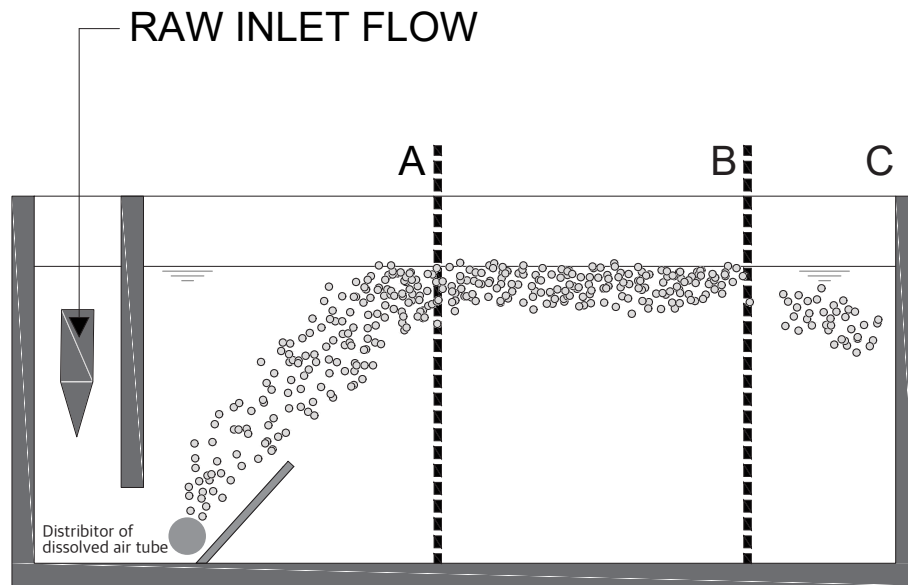
DAF is an alternative clarification process that uses micro air bubbles or nano air bubbles to attach and float flocculated particles and suspended solids to the water surface for removal. DAF is a cost-effective alternative to conventional sedimentation process. In contrast, sedimentation process removes settled solids from the bottom. DAF process is often heavily dependent on coagulant and flocculants to maximize particle collision rates and produce floc. A major difference of DAF process and other flotation processes lies in the volumes of bubbles, amount of air and raising speeds.

One macro bubble can be 1000 times bigger in volume compared to one micro bubble. And vice versa the number of micro bubbles can be 1000 fold in number compared to one macro bubble having same volume.

Microbubble DAF is an enhanced method to float particles to the surface with the aid of adherent micro air bubbles(size 20~70  $\mu\text{m}$ ). The advantages of this technology are their ability to treat a wide range of suspended solids in water at a high rate of solids removal. The adherence of suspended solids to bubbles is easier and more intensive, the smaller the bubbles are. Because of the improved adherence capacity of small microbubbles, the saturation of the introduced air lead to an improved suspended solids reduction, a higher solids content in the float sludge and a more stable float sludge on the surface of the microflotation cell.

Size distribution and rise rate of microbubble is an important parameter of microbubble DAF in water and wastewater treatment. A distribution of bubble sizes between 20 and 70 microns is the necessary requirement for an optimum flotation result. Even a small number of bubbles with diameters of above 100 microns can disable a flotation separation process, because larger bubbles rise more quickly and cause turbulence, which severely destroys already build air-flocks-agglomerates. The rise rate(3~10 m/h) is slow enough not to destroy the fragile flocks forming an agglomeration of particles with weak mutual bonding and high enough to allow time for separation of the agglomeration. With the attachment of particles to bubbles the size range of 「flock-bubble」 grows, and the rise velocities grow simultaneously. The separation rate is accelerated leading to residence times of combined chemical precipitation and flotation from 10 to 60 minutes with need of small footprint areas of treatment plants and decreasing the cost structures of treatment processes. Meanwhile, the change in nozzle size affects significantly on the microbubble rather than that in pressure. Also, at a fixed pressure, the treatment efficiency increased with the decrease in nozzle size or the increase in pressure. Finally, the change in pressure and nozzle size can be controlled microbubble diameter and improved treatment efficiency without the additional investment.

Microbubble DAF operate effectively over a wide range of hydraulic and solids loading.



(Figure) Flotation chamber(CEPIS, 1992)

Meanwhile, Nanobubbles are extremely small gas bubbles that have several unique physical properties that make them very different from normal bubbles. Nanobubbles( $<200\text{nm}$ ) are the smallest bubble size known, 500 times smaller than a microbubble( $200\text{nm} \sim 100,000\text{nm}$ ), or about the size of a virus. At this scale, far more nanobubbles can fit in the same volume of water compared to other bubbles. They also have several unique characteristics directly related to their miniature size that includes neutral buoyancy, a strong electric charge, and a high transfer efficiency. Larger bubbles do not possess these characteristics, making them less beneficial in a number of applications when compared to nanobubbles.

Nanobubbles have more than 500 times the surface area of a typical microbubble, measured at 40 micrometers in diameter. The larger surface area allows for increased mass transfer, ensuring virtually any gas is effectively delivered to water.

All bubbles naturally possess a surface charge. The smaller the bubble, the stronger the surface charge. Nanobubbles have a high zeta potential, which is the electro kinetic potential in colloidal dispersions. The negative charge combined with their high concentration improves separation efficiency in flotation processes by increasing collision probability. As mentioned above, these unique properties enable nanobubble floatation technology to be more efficient, typically consuming only 10%-to-20% of the energy consumption of conventional methods, and help ensure compliance with environmental regulations.

The neutral buoyancy and negative surface charge of nanobubbles allows them to remain in suspension for months at a time. This occurs even after the solution reaches oxygen saturation. The negative surface charge of nanobubbles limits bubble coalescence, ensuring they stay separated in solution. The bubbles charge, in combination with the high concentration of nanobubbles delivered to the wastewater by generator, increases the probability of collision with suspended matter and improves floatation rates.

The gas-injection rate through bubble generator is adjustable, enabling operators to manipulate the size of bubbles produced. As bubble size decreases so does its buoyancy and subsequently its rise rate. A lower rise rate is advantageous for froth flotation of coarse particles and hard-to-float suspensions that require relatively long residence times. A more rapid rise rate may be acceptable for larger, more buoyant particle removal.

The nanobubbles act as a gas reserve in the solution. As oxygen is consumed from the water by off-gassing, the nanobubbles rapidly diffuse more oxygen into the water, maintaining elevated dissolved oxygen levels until the nanobubbles are depleted.

#### <Advantages>

- Low cost and high efficiency
- Operates at 1/3 electrical HP compared to others.
- Eliminates costly polymer usage.
- Stable performance, low noise, easy to maintain
- Made in the Korea

#### <Application> CH-DAF can be used as:

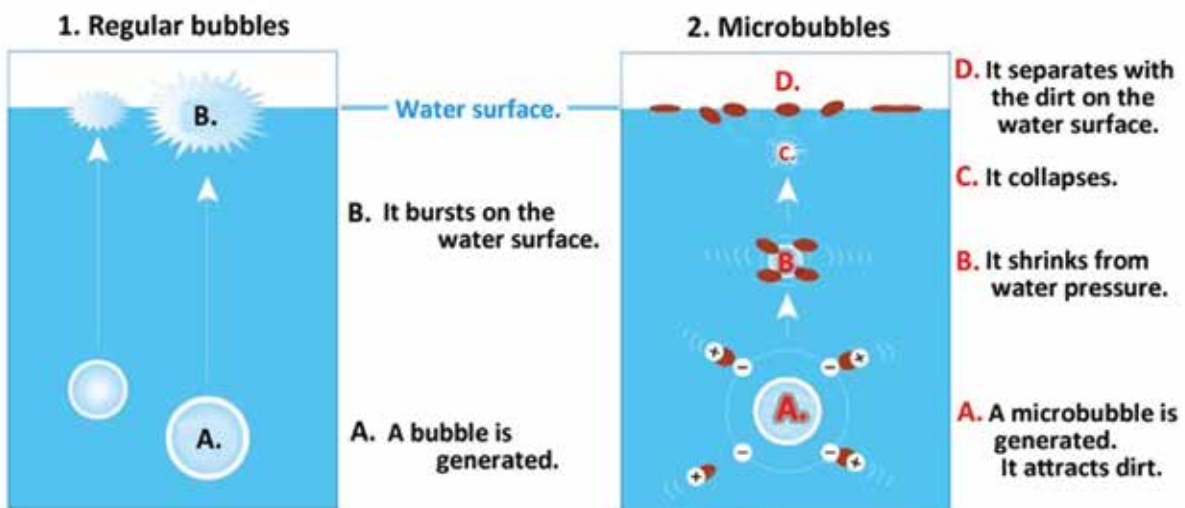
- BOD & COD & TSS reduction. heavy metal & color removal
- Primary treatment
- Tertiary treatment
- Replacement or protection of filtration units
- Sludge thickening
- Protection and performance improvement of MBR units



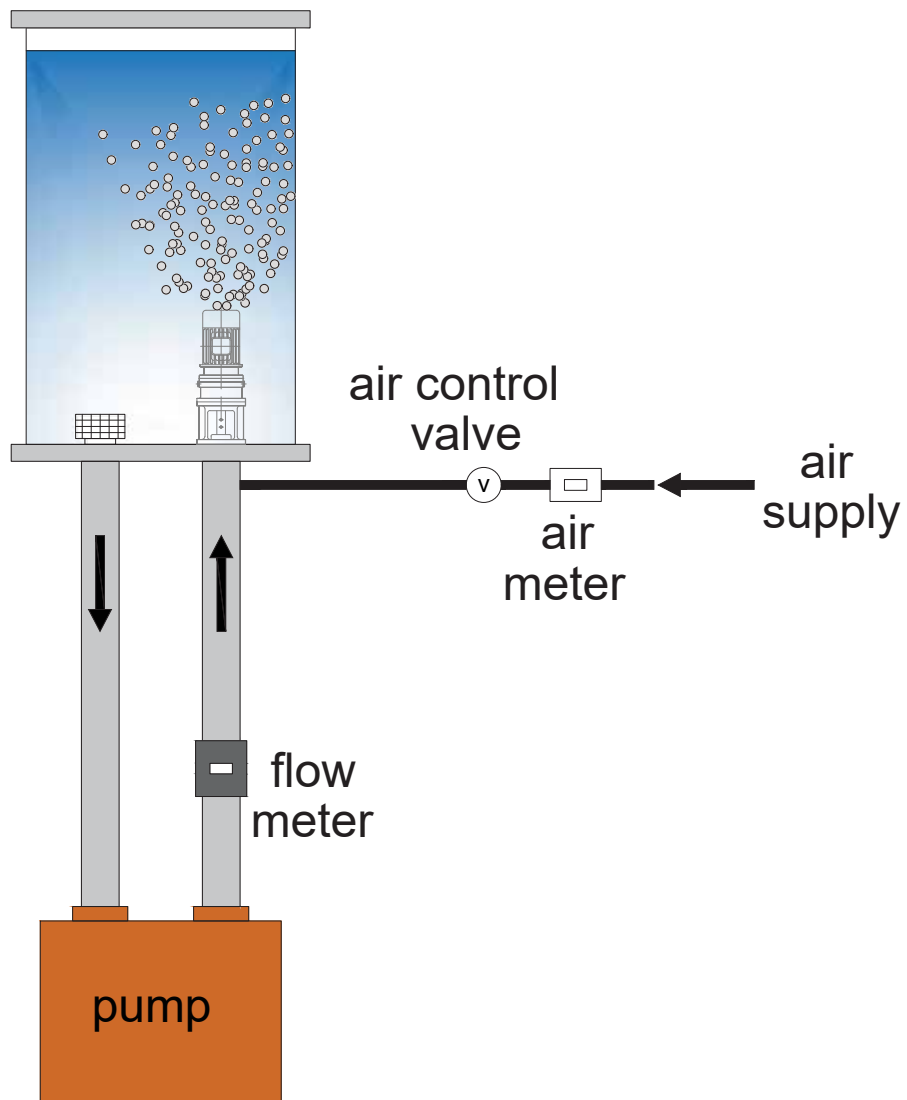
**Regular bubble**  
(approx. 2 mm)



**Microbubble**  
(approx. 20  $\mu\text{m}$  or 0.02 mm)



(Figure) Microbubble generation





## Water pollution prevention technology

### □ Dimethylformamide Wastewater Treatment

DMF(N,N-Dimethylformamide) is an organic solvent produced in large quantities throughout the world. It is a colourless liquid at room temperature with a faint amine odour. The molecular mass of DMF is 73.09, as calculated from its empirical formula ( $C_3H_7NO$ ).

DMF is a water-miscible polar solvent that is used in a wide variety of chemical industries. It is a powerful solvent for a variety of organic, inorganic, and resin products. It is completely miscible in all proportions with water and most organic solvents and has a relatively low vapour pressure. Also, at temperatures below 100°C, DMF remains stable in relation to light and oxygen. Temperatures in excess of 350 °C are required for DMF to decompose into carbon monoxide and dimethylamine. DMF sold commercially contains trace amounts of methanol, water, formic acid, and dimethylamine.

Because DMF is water miscible, it is difficult to remove it effectively by these physicochemical processes. Wastewater containing DMF is difficult to biodegrade directly.

The main pollutant, DMF was decomposed to dimethylamine and formate under alkaline conditions, and the dimethylamine was stripped out by the biological treatment process. The pretreated wastewater was then degraded in advanced treatment process.

Also, N,N-dimethylformamide(DMF) containing wastewater can be treated through aerobic DMF-hydrolyzing activated sludge and anaerobic digested sludge inoculated membrane separation process. Under a low organic loading rate, anaerobic membrane bioreactor maintained excellent DMF removal efficiency along with high methane conversion. To handle high organic loading rate, an appropriate solution is to maintain a low F/M ratio by increasing both the influent DMF concentration and sludge concentration.



DMF (Dimethylformamide) Wastewater treatment plant

# Chunghae ENV Environmental pollution prevention technology

## Water pollution prevention technology

- Electrochemical treatment
- Microbubble flotation technology
- Dimethylformamide wastewater treatment

## Air pollution prevention technology

- Thermal oxidation
- Scrubbing
- Chemical absorption of H<sub>2</sub>S for biogas purification

## Air pollution prevention technology

### □ Thermal oxidation(TO)

Commonly, VOCs(Volatile organic compounds) are emitted by manufacturing facilities as part of their processes. These VOC's are typically referred to as solvent fumes, hazardous air pollutants, hydrocarbons, halogenated hydrocarbons and other odorous emissions.

The pollutants in the exhaust air converted into non-hazardous substances above a certain temperature. This temperature is generally very high: between 700 and 800°C. As a large amount of energy is needed to heat the exhaust air to this temperature, a catalyst is used to reduce the reaction temperature and therefore also the energy consumption. This allows the reaction temperature lowered to between 250 and 400°C, which leads to considerable energy and cost savings.

To ensure that the pollutants can converted without problem, two factors need to taken into account. Firstly, the temperature of the exhaust gas must exceed a certain minimum level to ensure that a reaction takes place in the catalyst. A heat exchanger generally used to transfer the energy from the purified air to the exhaust air. As a result, the exhaust air can heated to the temperature necessary for a reaction in the catalyst. Secondly, depending on its composition, the exhaust air may need preconditioning so that unwanted particles can removed.

This is necessary to prevent catalyst poisoning, which deactivate the catalyst, making it unusable and unable to perform. Catalyst poisons cover the surface of the catalyst and slow down its effect or prevent it from functioning altogether. For this reason, this air pollution control system of CHENV can only applied with exhaust air containing certain kinds of pollutants. If a pollutant that is a catalyst poison needs to remove from the exhaust air, a catalytic combustion system is not a suitable choice.

A thermal oxidizer(also referred to as a incinerator) is a combustion device that controls VOCs by converting (destroying) to CO<sub>2</sub> and H<sub>2</sub>O through the use of heat.

The simplest technology of thermal oxidation is direct-fired thermal oxidation (combustion). A process stream with hazardous gases is introduced into a firing box through or near the burner and enough residence time is provided to get the desired destruction removal efficiency of the VOCs. Most direct-fired thermal oxidizers operate at temperature levels between 800 °C and 1,200 °C with air flow rates of 0.24 to 24 standard cubic meters per second.

Three main factors in designing the effective thermal oxidizers are temperature, residence time, and turbulence. The temperature needs to be high enough to ignite the exhaust gas. Most organic compounds ignite at the temperature between 590°C and 650°C. To ensure near destruction of hazardous gases, most basic oxidizers are operated at much higher temperature levels. When catalyst is used, the operating temperature range may be lower. Residence time is to ensure that there is enough time for the combustion reaction to occur. The turbulence factor is the mixture of combustion air with the hazardous gases.

Thermal oxidizer system is integrated to our customized PLC-control panel. System communicates with the thermal oxidizer system for optimal performance, safety, and reliability. System optimizes fuel efficiency by managing temperatures, controlling drives, and positing valves. This user friendly system provides automated operations, one button start-stops, self diagnostics, and data monitoring options for simplified maintenance.

CHENV.Inc supplies very efficient thermal combustion system that use a technology solution, which has been proven over a number of years to be suitable for the destruction of high levels of VOCs. CHENV.Inc offers many different types of VOC abatement systems including catalytic oxidizers. Our goal is to offer the highest-quality and most reliable VOC thermal oxidizer systems for each specific application. Our team is capable of providing complete support from the initial concept all the way through installation and into the commissioning. For each unique thermal oxidizer design project, we utilize our experience and expertise to create the best overall system at the most efficient thermal oxidizer cost.

## ▷ Catalytic oxidizer

Catalytic oxidizer(also known as catalytic incinerator) is another category of oxidation systems that is similar to typical thermal oxidizers, but the catalytic oxidizers use a catalyst to promote the oxidation. Catalytic oxidation occurs through a chemical reaction between the VOC hydrocarbon molecules and a precious-metal catalyst bed that is internal to the oxidizer system. A catalyst is a substance that is used to accelerate the rate of a chemical reaction, allowing the reaction to occur in a normal temperature range between 250 °C and 540 °C.

VOCs destruction occurs by chemical reaction, typically a catalytic oxidizer will achieve destruction efficiencies of 95~96% and operate between 250°C to 400°C. While direct combustion exhaust treatment system works at high temperatures from 700°C to 850°C, which uses a catalyst for treatment, can operate at low temperatures from 250°C to 300°C. It has a high margin regarding the space velocity value(exhaust gas volume/catalyst volume), and delivers high treatment efficiency with malodorous organic gas components even at low temperatures. Higher destruction efficiencies may be achieved by adding more catalyst and may also result in operational fuel saving of 40~60%. Also, Catalytic oxidizer are easy to install, provide very high removal efficiency, and offer very low operating cost. Therefore catalytic oxidizer is applied to a broad range of industrial processes(painting, printing, chemical, rubber, metal-casting, and food processes, etc).

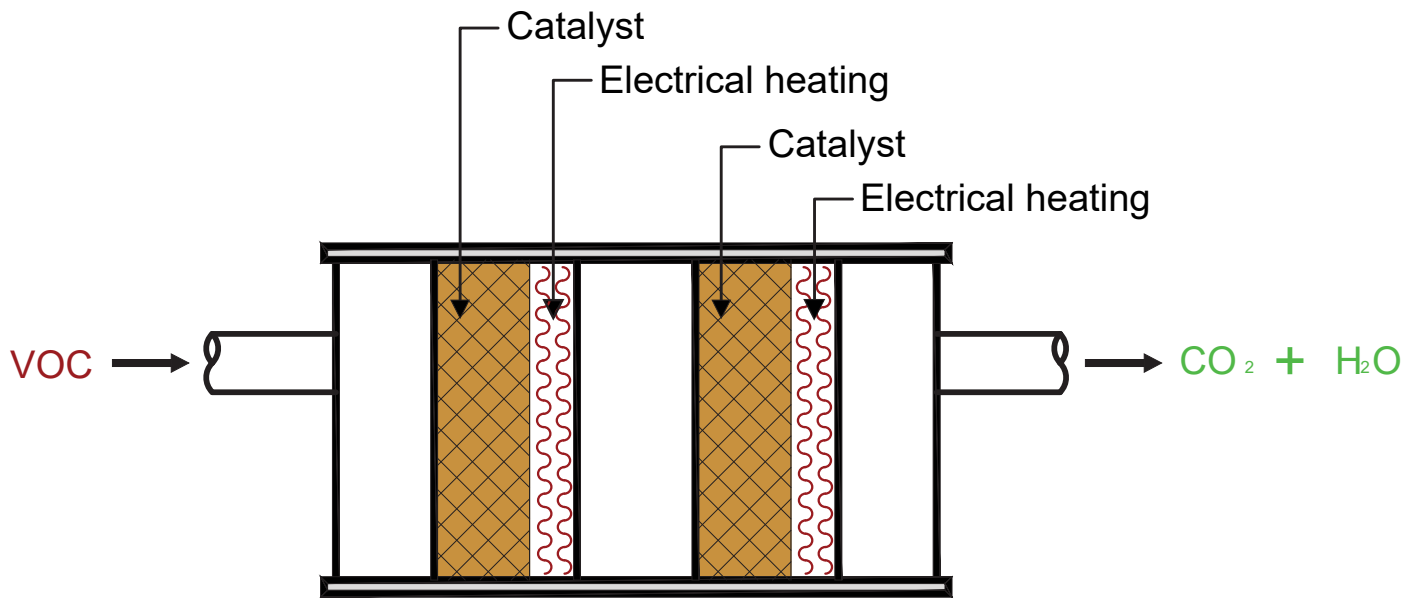
## ▷ Regenerative thermal oxidize

Regenerative thermal oxidations(RTO) is considered among the world's most advanced thermal oxidation systems.

RTO are engineered to provide the most advanced and efficient thermal destruction of VOCs by oxidation. With thermal efficiencies of up to 97%, and destruction efficiencies that can exceed 99%, RTOs will give you the highest possible removal rates at the lowest cost. One of today's most widely accepted air pollution control technologies across industry is a RTOs. RTOs are used for abating solvent fumes, odours, etc. from a wide range of industries. It is suitable for the treatment of high concentration gases.

RTOs use a ceramic bed which is heated from a previous oxidation cycle to preheat the input gases to partially oxidize them. The preheated gases enter a combustion chamber that is heated by an external fuel source to reach the target oxidation temperature which is in the range between 760°C and 820°C. The final temperature may be as high as 1,100°C for applications that require maximum destruction. The air flow rates are 2.4 to 240 standard cubic meters per second.

The ceramic heat exchanger can be designed for thermal efficiencies as high as 97+%. RTO's standard heat exchanger consists of two towers, with a heat storage material packed in each. A target gas goes through the heat storage material in one tower and is heated to about 750°C, it then enters the reaction chamber in the upper part of the tower, where the gas is heated to 800°C or higher by a burner so that organic solvents contained in the gas are oxidized and decomposed. The cleaned hot air then flows into the other tower, moving down while releasing heat into the heat storage material. The damper at the intake repeatedly switches the operation between heat storage and release within the two towers.



## Air pollution prevention technology

### □ Scrubbing

Air quality is a major concern of many citizens, scientists and policy makers. Odors and gases emitted from industrial production, waste management and power generation, and other economic activities threaten both public health and environmental sustainability. Fortunately, as engineers and technicians seek new designs to avoid such emissions, technology affords a way to mitigate odor rising from factories and public utilities, particularly sewage treatment plants.

Generally, the exhaust gas or odor is treated through an absorption process. The air pollution control industry has been using scrubbing to tremendous success for many years. Scrubbing is a proven and effective technology to blunt unpleasant odors and exhaust gases. Scrubbing can remove pollutants whether the airstream contains gases, liquid or solid particulate matter — which is a huge advantage that scrubbing can offer.

When there are several pollutants present in a gas stream, it's customary to choose scrubbing to clean. Scrubbing have the ability to first remove gas contaminants through diffusion. Then, the liquid and solid particulates are then removed in a second stage through either inertia impact, cyclonic motion or by interception. Once the polluted air exhaust gas has been run through scrubbing, it's then expelled out of the scrubbing system with 99% of the contaminants removed. Although all scrubbing odor control systems operate using the same chemical principles, they are not all the same.

### ▷ Wet Scrubber

A wet scrubber is the generic name of a control device that uses the process of absorption to separate the pollutant from industrial exhaust gases.

When using a wet scrubber, flue gas is funneled through an area and sprayed with a wet substance. Water is the most common scrubbing liquid. Water is used when dust and particulate matter is to be removed, but other chemicals can be added.

Water has a relatively low cost, and control loops allow for some degree of recirculation, which helps to lower the fresh water addition to the system. However, if certain pollutants require a modified solvent, additional chemical costs can quickly increase the total cost of solvent use. These chemicals are chosen to specifically react with certain airborne contaminants—generally acidic gases.

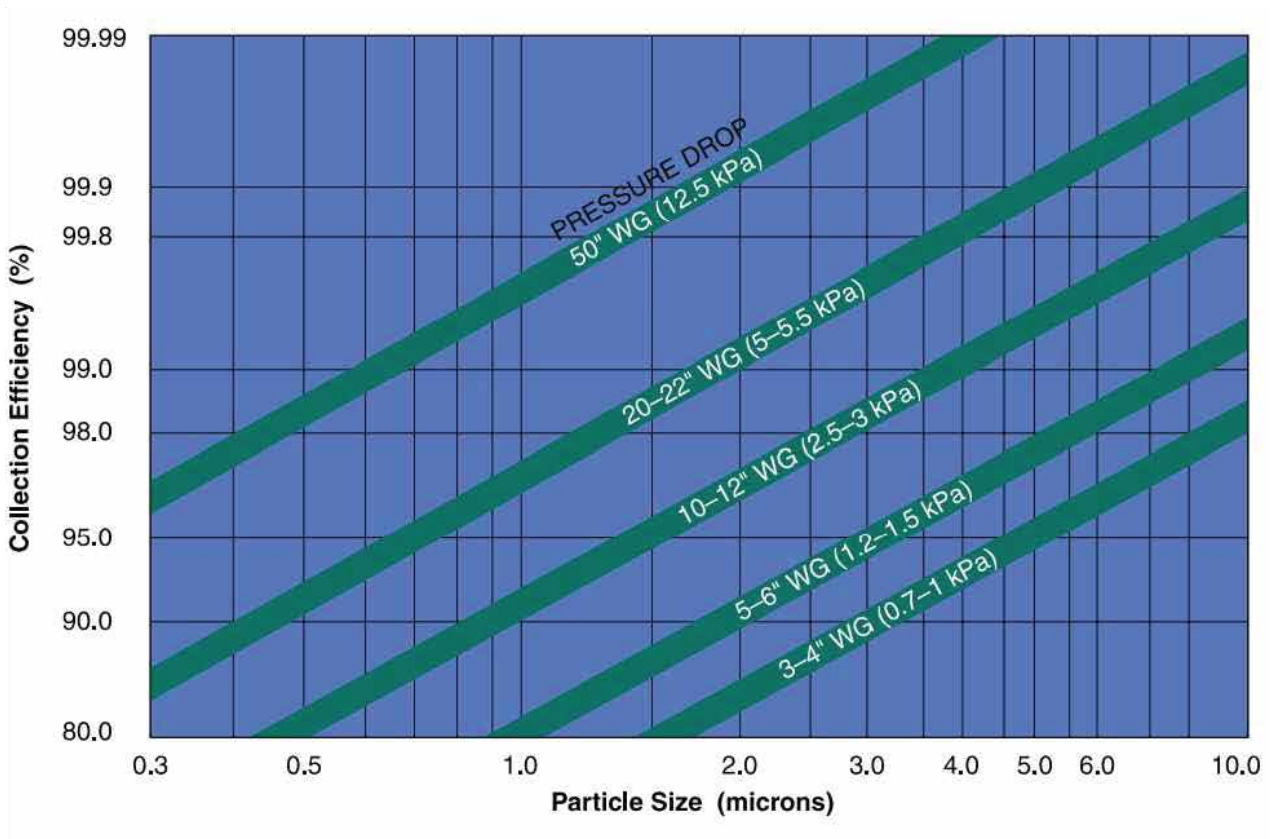
This process adds significant amounts of vapour to the exhaust—which causes the release of exhaust that appears as white smoke when vented.

The most common type of wet scrubber is a packed-bed counterflow scrubber. There are other types of scrubbers, such as cross flow, bubble plate and tray scrubbers.

One of the determining factors in calculating the performance capability of a wet scrubber is understanding the pollutants' solubility in water. Calculating the relationship of the pollutants' solubility in a scrubbing fluid is called the absorption equilibrium.

Collection efficiency of wet scrubbers can usually be related to pressure drop. This graph shows the efficiencies obtainable for various pressure drops from 0.3 to 10 microns. The actual performance of a given scrubber will depend on the specific dust characteristics and the amount of scrubbing water.

The principle drawback to using a wet scrubber for organic pollutant removal is the transference of an air pollution control problem to a water (liquid) pollution control problem. For most organic pollutants, maintenance impacts will be low. However, if the target gas stream has particulates or biological impurities, these can increase the potential for plugging media, biologic growth, and pump and piping degradation.



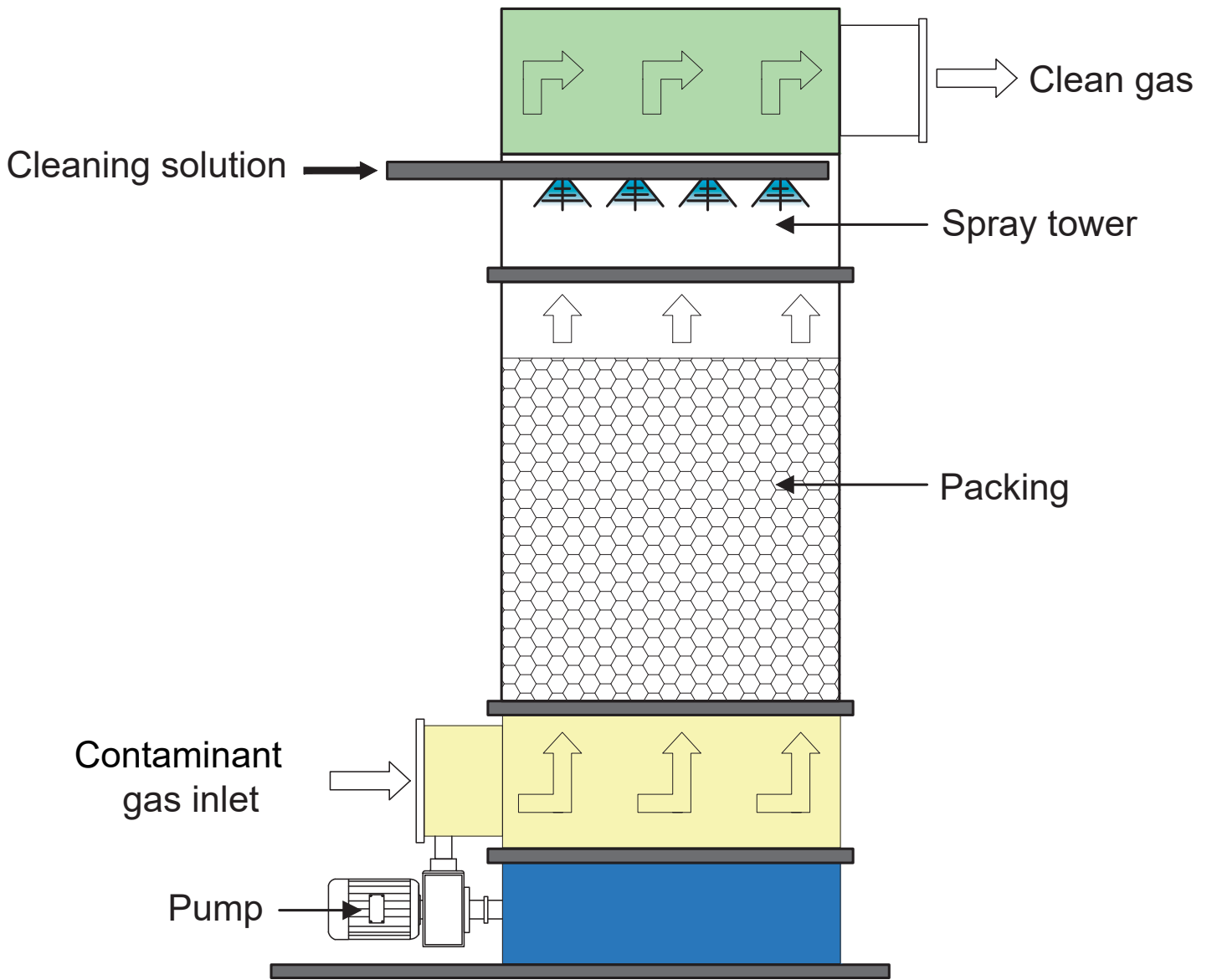
(Figure) Efficiency guide

The sketch below provides a very basic flow diagram and points out the common components of a crossflow wet scrubber. The gas stream that contains the pollutants to be removed enters from the bottom of the scrubber and quickly turns upward towards the exhaust at the top of the scrubber. The random packing provides necessary surface area to distribute the liquid solvent and encourage contact between the two medias. The liquid scrubbing media (or solvent) enters near the top of the scrubber and is distributed over the random packing. The liquid adsorbs the pollutants from the gas phase. Prior to exiting the scrubber, the gas exits to the atmosphere.

When your company's engineers are considering scrubbing equipment, they must consider the system's capacity. Check out the available capacity of the system's units, inquire about the pressure drop, the required removal efficiency and how reliably the scrubbing system operates. These factors together will determine the effectiveness, affordability and longevity of your scrubber.

Chunghae ENV Co.,Ltd. has the industry experience to give you the customized scrubbing solutions you desire.







## Air pollution prevention technology

### □ Chemical absorption of H<sub>2</sub>S for biogas purification

Biogas, depending on its origin (food waste, livestock manure, landfill wastes, sewage sludge), have different composition. Methane (CH<sub>4</sub>, 45~75%) and carbon dioxide (CO<sub>2</sub>, 25~50%) are the main constituents, but biogases also contain significant quantities of undesirable compounds (contaminants), such as hydrogen sulfide (H<sub>2</sub>S), ammonia (NH<sub>3</sub>) and siloxanes.

Biogas emissions can cause damage to the environment due to the presence of the pollutant H<sub>2</sub>S, which H<sub>2</sub>S represents one of the most harmful sulfur compounds for environment and equipment. At lower concentrations, this gas has an unpleasant odour; at higher concentrations, it can be life-threatening.

On the other hand, Biogas is a valuable renewable energy source due to its high methane content. Therefore biogas shall be recognised as a sustainable major alternative resource of fuel, electricity in the near future. However, direct utilization of biogas as fuel without removal of H<sub>2</sub>S leads to the formation of sulfur dioxide (SO<sub>2</sub>), which is another toxic pollutant and a major contributor to acid rain in the atmosphere.

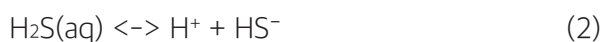
### ▷ Reaction mechanism

The H<sub>2</sub>S was removed by means of chemical absorption in an iron-chelated solution, which converts H<sub>2</sub>S into elemental sulphur (S).

Basic redox reactions employed for adsorption and regeneration. The process of chemical absorption of H<sub>2</sub>S into iron-chelated solution offers many advantages, such as the high efficiency of H<sub>2</sub>S removal, the selective removal of H<sub>2</sub>S and the low consumption of the chemicals because iron-chelated solutions functions as a pseudo-catalyst that can be regenerated. Regeneration is achieved by aeration, converting the sulfide to elemental sulfur.

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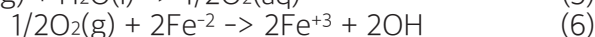
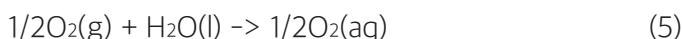
In processes based on iron chelating, H<sub>2</sub>S is initially physically absorbed into water undergoing the dissociation according to reactions 1, 2 and 3.



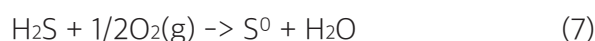
The formation of S occurs by means of sulphide oxidation by the chelated iron according to the reaction described by Equation (4).



Regeneration of the aqueous iron-chelated solution occurs by means of its oxygenation, according to Equation (5), followed by conversion of the pseudo-catalyst into its active form Fe<sup>+3</sup> [Equation (6)].



The overall reaction is expressed in Equation



Several chelate agents that can be used for the specific proposal of reaction (7) have been studied in the literature (Wubs and Beenackers, 1993), with the EDTA (ethylenediaminetetraacetate) being the most common chelate used.

▷ features

- In this process, the total removal of H<sub>2</sub>S depends on absorbent(Fe/Organic acids catalyst solution) concentraion, pH, temperature, adequate ratio of gas to liquid flow-rates and contact time.

- The Fe/Organic acids catalyst solution is nontoxic, and it operates at ambient temperatures. The Fe/Organic acids catalyst is potentially attractive for biogas applications because it is 99+% effective.

▷ Application

In the first phase of the application, the treatment system will be applied to livestock waste treatment facilities and food waste resource recovery facilities of local government and industries. In the second phase of the application, the treatment system will be applied to a petrochemical plant, heat power plant, combined heat & power plant which can produce sulfur compounds and its related industry.

