

Advanced Water Treatment Plant

The case study of Ozonation and
Granular Activated Carbon(GAC)

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Hello! Sawasdee (krub)! Min-Ga-La-Ba!



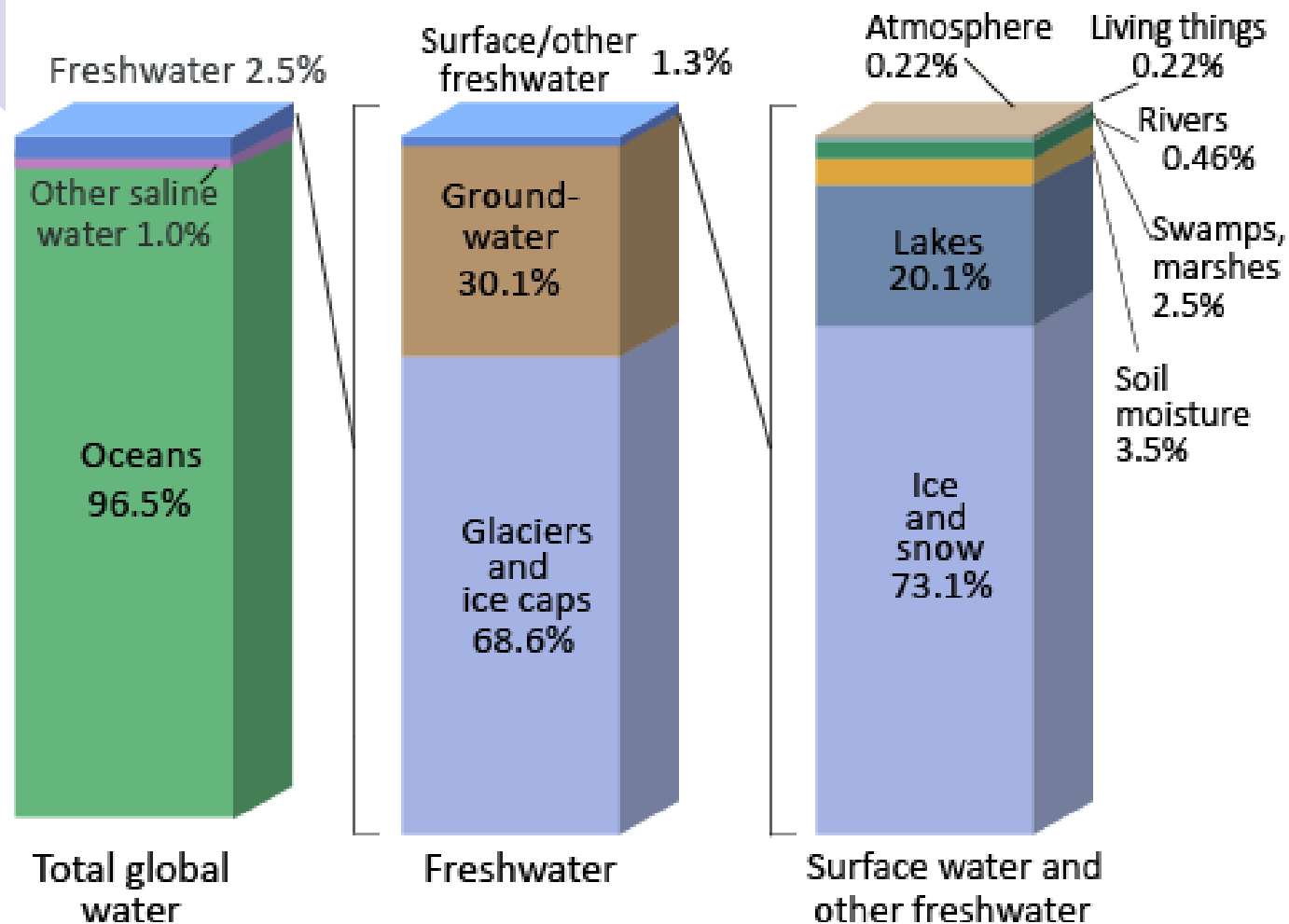
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Some interesting facts about WATER!

- **How much water is there on earth?**
 - Most of the earth consists of water, there is much more water than there is land.
 - About 70% of the earth's surface is covered in water. But water also exists in the air as vapour and in aquifers in the soil, as groundwater.
- **How much of the water can be found in oceans?**
 - As oceans are very wide and there are multiple to be found on earth, oceans store most of the earth's water. This is apparently 97% of the total amount of water on earth, 2% of which is frozen.
- **How much freshwater is available?**
 - Of all the water on earth, which is 97.14% of the total amount of surface water, only 2.59% is freshwater. Of this 2.59% another percentage is trapped in ice caps and glaciers, which is about 2%. The rest of the freshwater is either groundwater (0.592%), or readily accessible water in lakes, streams, rivers, etc. (0.014%)
- **How much water is suitable for drinking water?**
 - From the quantities that came up in the questions listed above, one can conclude that less than 1% of the water supply on earth can be used as drinking water.

Where is Earth's Water?



Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, *Water in Crisis: A Guide to the World's Fresh Water Resources*. (Numbers are rounded).

● <http://ga.water.usgs.gov/edu/earthwherewater.html>

The **FACTS** about **BOTTLED WATER**

While a large portion of the world desperately seek clean drinking water, the United States and other countries, spend billions on bottled water when perfectly clean drinking water is readily available. Not only are we needlessly spending money on water with lower standards than those of tap water, we are also filling our landfills with billions of pounds of oil based plastics that take 1000's of years to degrade. This graphic will visually present an overview of bottled water.



\$0.0015 / gal **\$10.00 / gal** The price of bottled water is up to **10,000 times** the cost of tap water

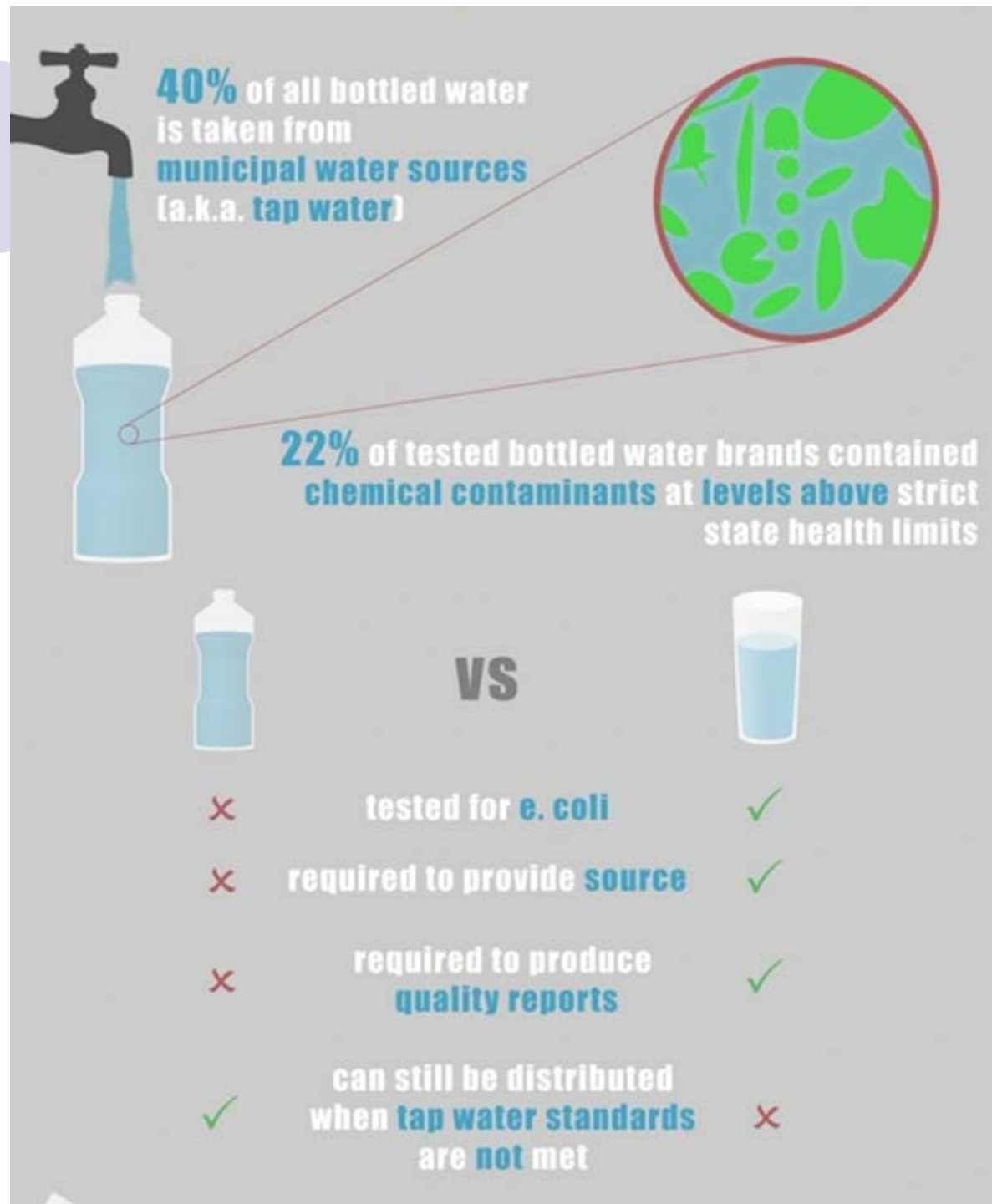


Which generates **\$61 billion dollars** **53 billion gallons** are consumed globally



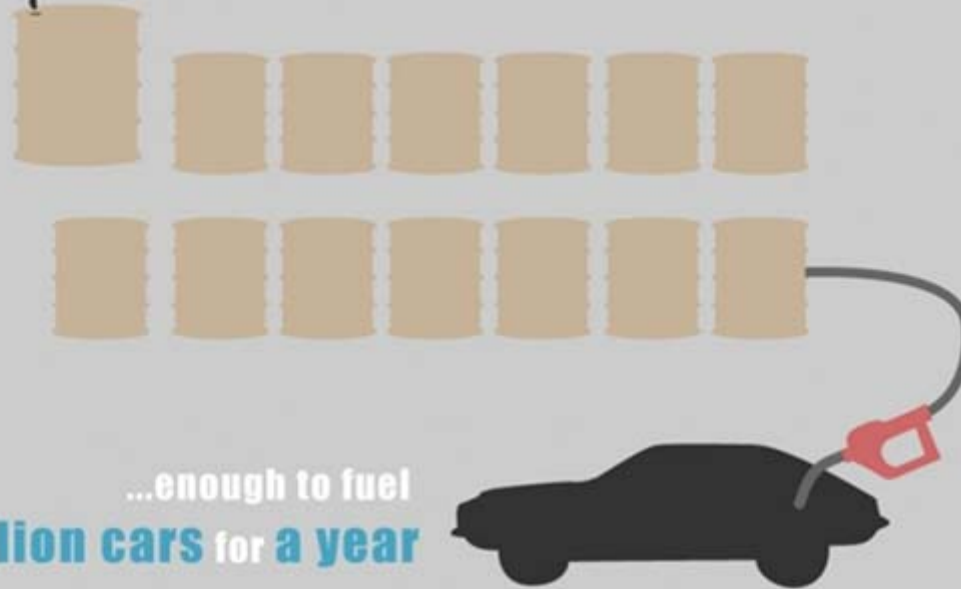
40% of all bottled water is taken from **municipal water sources** (a.k.a. **tap water**)





17 Million barrels of oil

are used in the production of water bottles yearly...



...enough to fuel
1 Million cars for a year



It takes **3x** the amount of water
to produce the bottle as it does
to fill it



Only 1 in 5 water bottles
are **RECYCLED**



A black silhouette of a car with a red fuel pump nozzle and hose attached to its rear, indicating refueling.

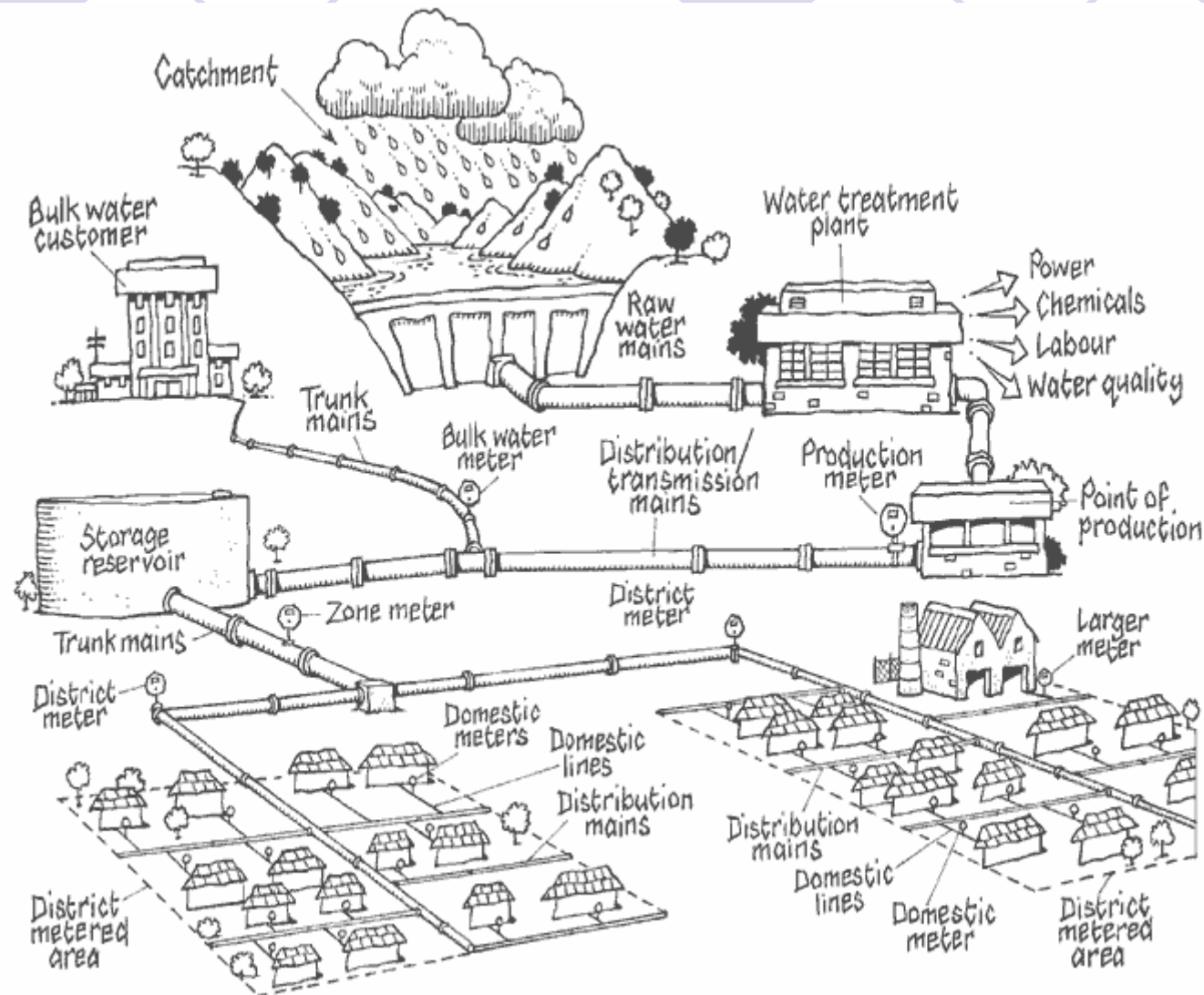
It takes **3x** the amount of water to produce the bottle as it does to fill it



Only 1 in 5 water bottles are RECYCLED

The other 4 contribute to the **3 billion pounds of waste** from plastic water bottles

Water Supply System



Agenda

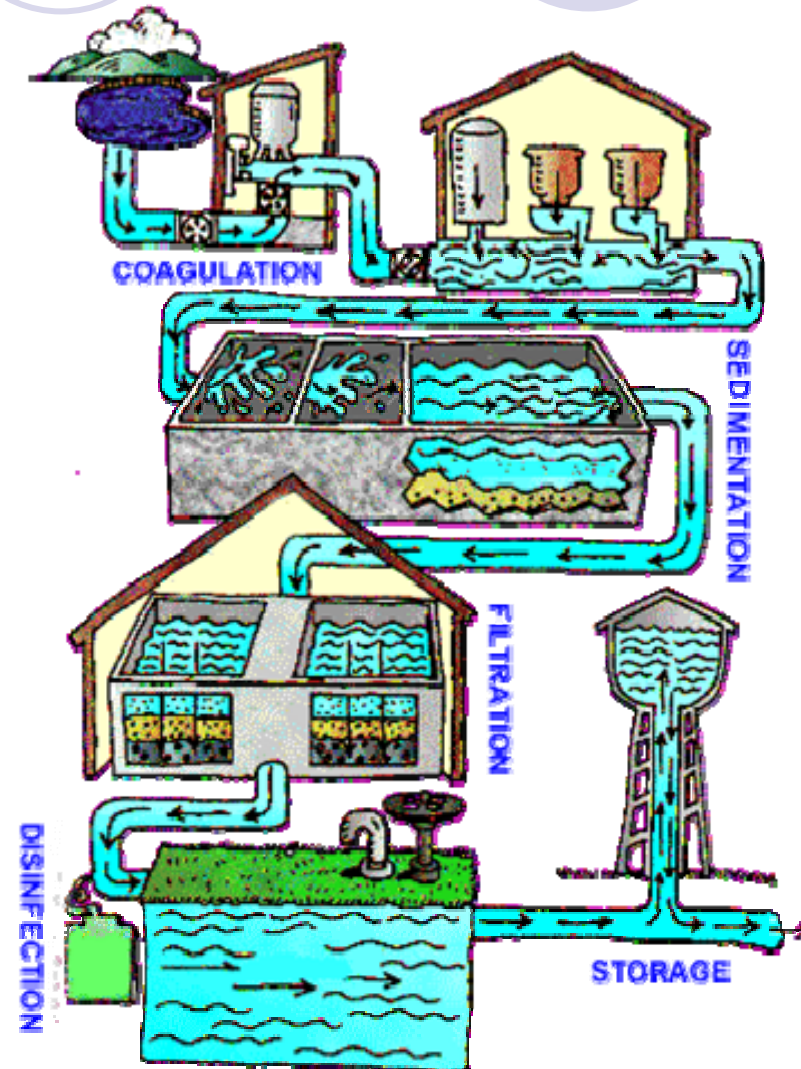


- What is “our” Advanced water treatment plant means?
- Ozonation
- Granular Activated Carbon(GAC)
- Some useful information of Japan and Korea Advanced Water Treatment plant

What is the conventional method to treat water? (1/2)

Many water treatment plants use a combination of coagulation, sedimentation, filtration and disinfection to provide clean, safe drinking water to the public. Worldwide, a combination of coagulation, sedimentation and filtration is the most widely applied water treatment technology, and has been used since the early 20th century.

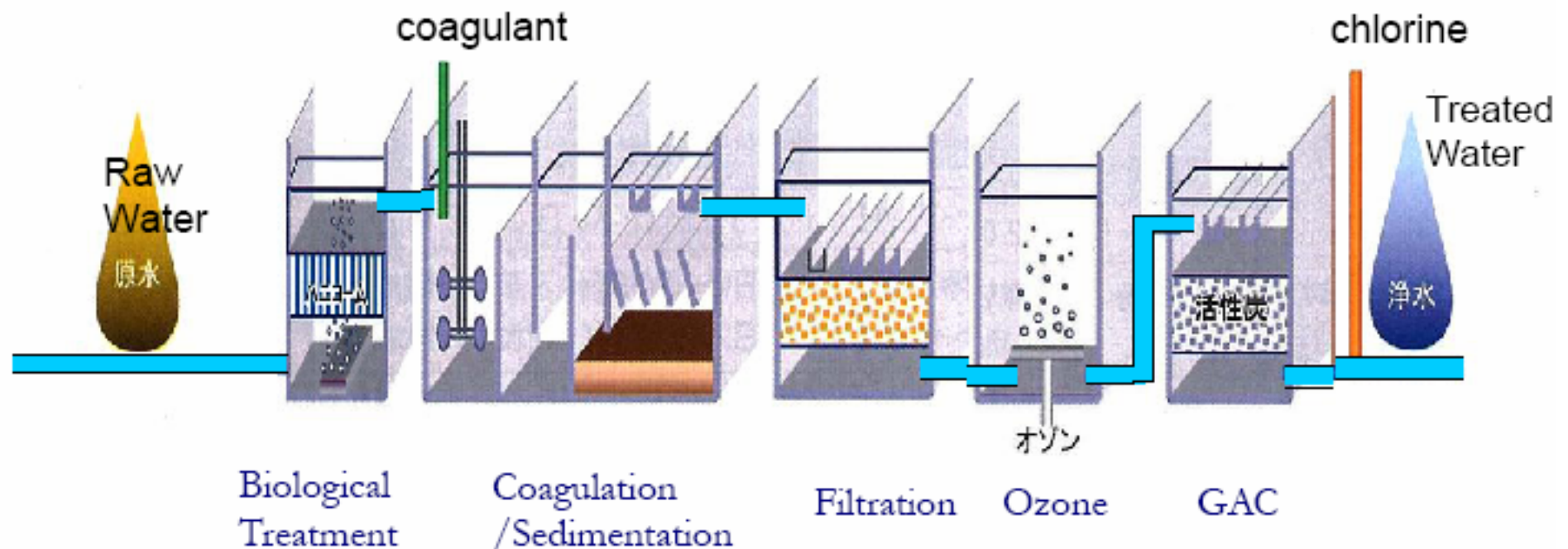
What is the conventional method to treat water? (2/2)



Why? Advanced Water Treatment Plant (Advanced WTP)

- Urbanization, Industrialization, Landuse, Climate, etc :
 - All change...change...change...
- Therefore;
 - Water pollution in rivers
 - Water quality of raw water taken deteriorated
 - Population affected by offensive taste and odor increased
 - Changes in “*water preferences*” over the last few decades

Typical flow diagram of Advanced Water Treatment



Ozonation system

- Facts:

- The ozonation process recently gained popularity as a treatment alternative in the united States after the regulatory agencies placed restrictions on the disinfection by-products, especially the acceptable levels of trihalomethane
- Ozonation system is an established and proven disinfection alternative, as well as a preoxidant for the control of THM precursors

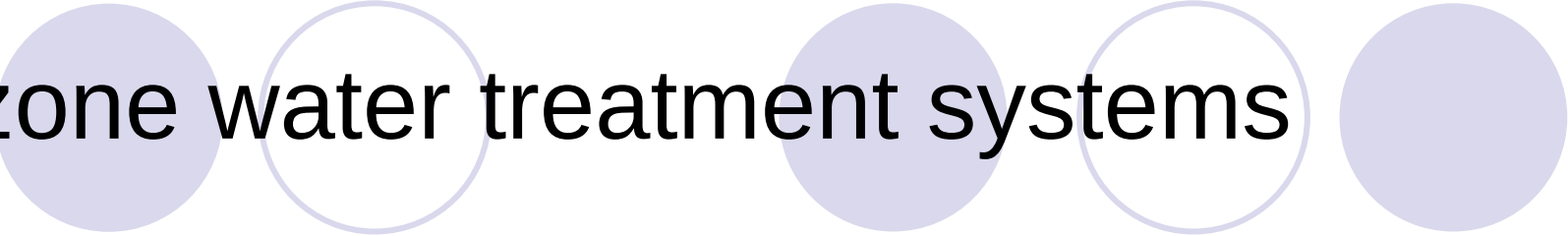
Ozonation system(2)

- Benefits:

- Disinfection...Very short disinfection times
- Oxidation and volatization of organics
- Control of algae and associated taste- and odor-producing compounds
- Destabilization(microflocculation) of certain types of turbidity
- Removal of color-causing compounds
- Oxidation of iron and manganese
- Partial oxidation of organics for subsequent removal by microorganisms

Ozonation: Design considerations and some design issues with respect to ozone generation and the ozone contact tank

- Ozonation: Design issues:
 - Selection of feed gas system
 - Preparation of the feed gas system
 - Selection of the ozone generator
 - Design of the ozone contact basin
 - Destruction of off-gas ozone



Ozone water treatment systems

- have four basic components:
 - a gas feed system
 - an Ozone generator
 - an Ozone contactor/ Ozone contact tank
 - an off-gas destruction system

Simplified Ozone System Schematic

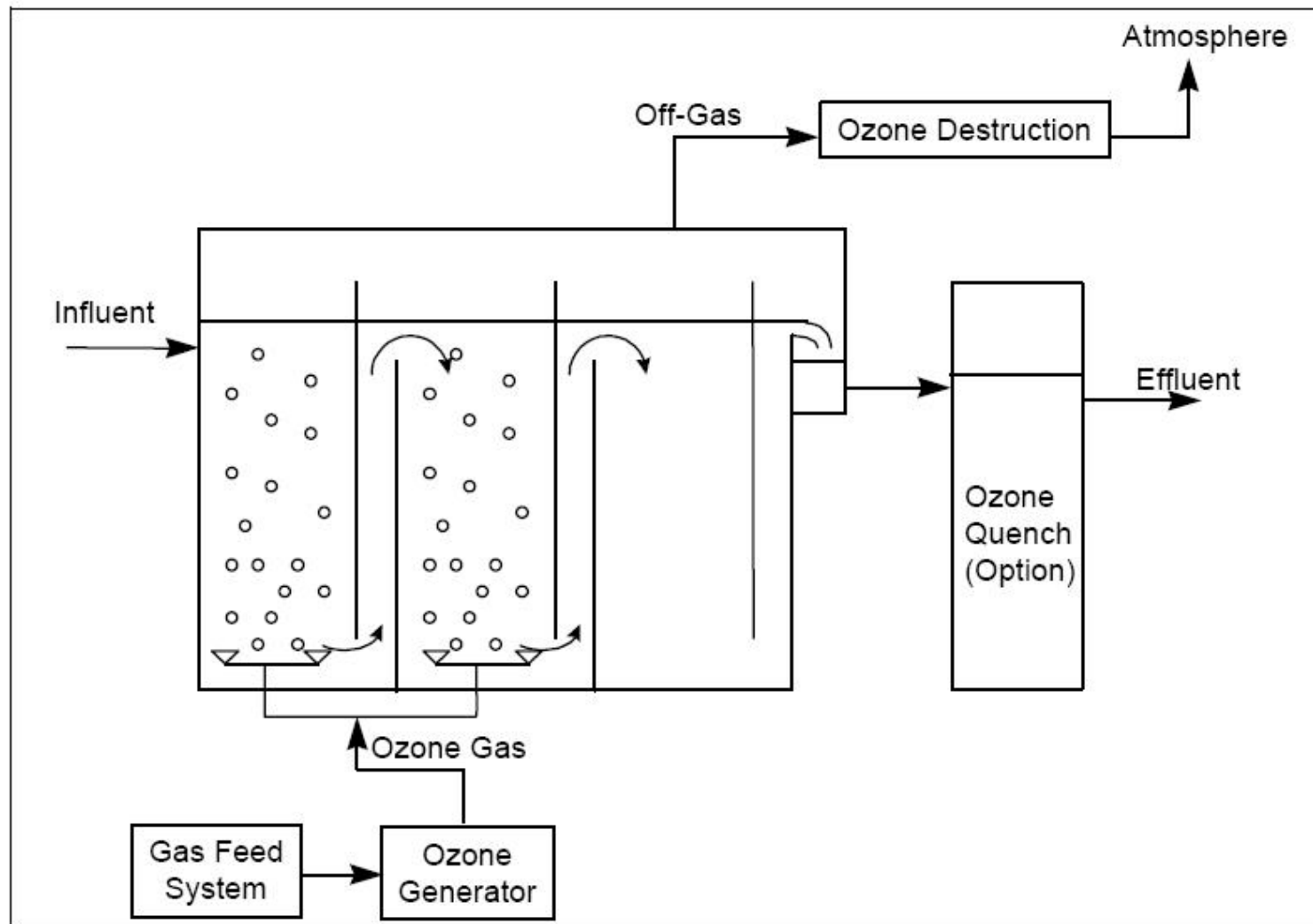


Figure 3-4. Simplified Ozone System Schematic

A gas feed system

Table 3-2. Comparison of Air and High Purity Oxygen Feed Systems

Source	Advantages	Disadvantages
Air	• Commonly used equipment • Proven technology • Suitable for small and large systems	• More energy consumed per ozone volume produced • Extensive gas handling equipment required • Maximum ozone concentration of 3-5%
Oxygen (general)	• Higher ozone concentration (8-14%) • Approximately doubles ozone concentration for same generator • Suitable for small and large systems	• Safety concerns • Oxygen resistant materials required
LOX	• Less equipment required • Simple to operate and maintain • Suitable for small and intermediate systems • Can store excess oxygen to meet peak demands	• Variable LOX costs • Storage of oxygen onsite (Fire Codes, i.e. safety concerns) • Loss of LOX in storage when not in use
Cryogenic Oxygen Generation	• Equipment similar to air preparation systems • Feasible for large systems • Can store excess oxygen to meet peak demands	• More complex than LOX • Extensive gas handling equipment required • Capital intensive • Complex systems to operate and maintain

Table 3-2 presents a comparison of the advantages and disadvantages of each gas feed system.

Ozone Generators

- The voltage required to produce ozone by corona discharge is proportional to the pressure of the source gas in the generator and the width of the discharge gap.
- Theoretically, the highest yield (ozone produced per unit area of dielectric) would result from a high voltage, a high frequency, a large dielectric constant, and a thin dielectric.
- However, there are practical limitations to these parameters. As the voltage increases, the electrodes and dielectric materials are more subject to failure. Operating at higher frequencies produces higher concentrations of ozone and more heat requiring increased cooling to prevent ozone decomposition. Thin dielectrics are more susceptible to puncturing during maintenance.
- The design of any commercial generator requires a balance of ozone yield with operational reliability and reduced maintenance.

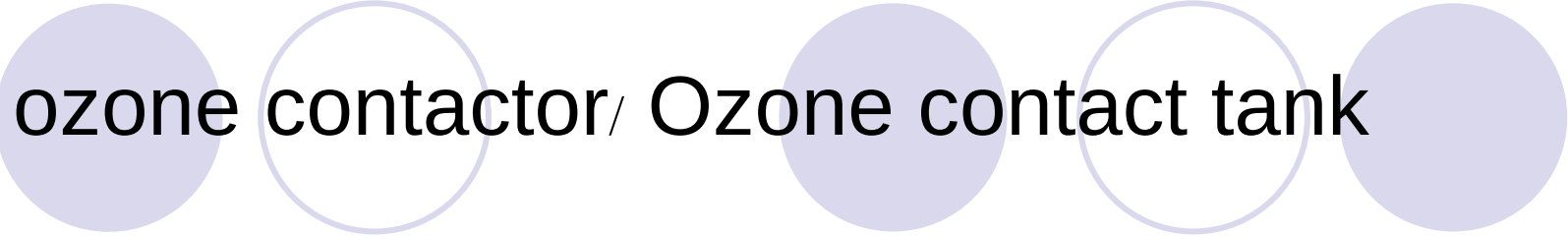
Ozone Generators

- Should know...
 - In the overall production of ozone, the electrical power is a critical element because the greater the power consumption the greater the heat generation.
 - Gas flow also affects the generation of heat; a gas flow that is too low will cause the generator to heat up, whereas as excessively high gas flow rate will decrease ozone production.

Ozone Generators



- After the type of ozone generation unit is selected, the design engineer must establish the following key design issues:
 - Size of the ozone generator
 - Number of generators
 - Cost of energy
 - Availability and cost of oxygen
 - Type of feed gas treatment system
 - Reliability of each component
 - Operation and maintenance costs
 - Ozone Contactor design
 - Destruction of the off-gas
 - Use of catalyst such as UV and hydrogen peroxide



An ozone contactor/ Ozone contact tank

- Once ozone gas is transferred into water, the dissolved ozone reacts with the organic and inorganic constituents, including any pathogens.
- Ozone not transferred into the process water during contacting is released from the contactor as off-gas.
- Transfer efficiencies of greater than 80 percent typically are required for efficient ozone disinfection (DeMers and Renner, 1992).
- The effective mixing of ozone and process water is critical in maximizing the performance of the ozonation system.

An ozone contactor/ Ozone contact tank

- Common ozone dissolution methods include:
 - Bubble diffuser contactors/ Diffused bubbles
 - Concurrent
 - Countercurrent
 - Injectors
 - Positive pressure injection (U-tube)
 - Negative pressure injection (Venturi tube)
 - Turbine mixers/ Turbine mixer tank
 - Packed tower
- The countercurrent bubble contactor is considered to be the most efficient and cost effective of the alternatives and has been employed in the design of most ozonation system
- Due to the rapid reaction kinetics of ozone, a contact time of only 3 – 10 min is considered to be a practical detention time for the contactor

An ozone contactor/ Ozone contact tank

- The tanks must be completely enclosed
- They are composed of concrete and are primarily located outside
- Each tank has two cells and is capable of handling 50% of the maximum daily flow of the plant
- Each cell should have a drain to allow periodic dewatering and cleaning
- Stainless steel hatches should be provided to facilitate inspection and maintenance
- A slight negative pressure(2 in. of water) should be maintained in the tank to ensure that there is no leakage of ozone above the water surface
- All pipe(SS304 or SS316) connections should be welded or flanged inside the tank and a check valve should be installed in the gas feed line prior to the contactor to prevent the backflow of water into the gas line
- The water depth of the tank should be 18-20 ft (5.5 – 6 m.) to provide a minimum ozone transfer efficiency of 95%.

Bubble Diffuser Contactors

- The bubble diffuser contactor is commonly used for ozone contacting in the United States and throughout the world (Langlais et al., 1991).
- This method offers the advantages of no additional energy requirements, high ozone transfer rates, process flexibility, operational simplicity, and no moving parts.
- Figure 3-7 illustrates a typical three stage ozone bubble diffuser contactor. This illustration shows a countercurrent flow configuration (ozone and water flowing in opposite directions), an alternating cocurrent/countercurrent arrangement, and a cocurrent flow configuration (ozone and water flowing in the same direction).
- Also, the number of stages can vary from two to six for ozone disinfection, with the majority of plants using two or three chambers for contacting and reaction (Langlais et al., 1991).

Bubble Diffuser Contactors

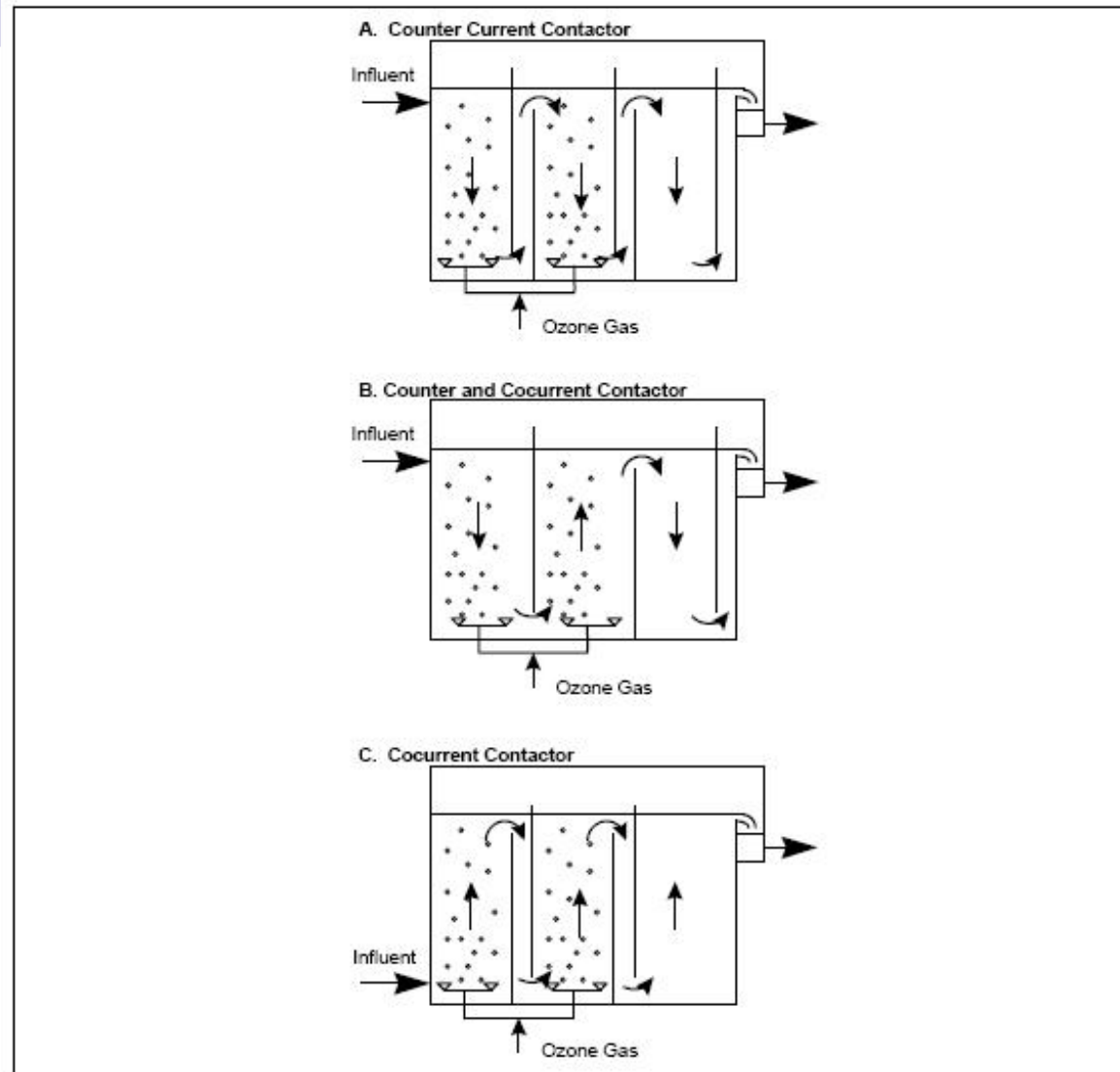


Figure 3-7. Ozone Bubble Contactor

Schematic of a three-stage, bubble diffuser ozone contact basin. (Adapted from EPA Design Manual, EPA/625/1-86/02, Oct. 1986)

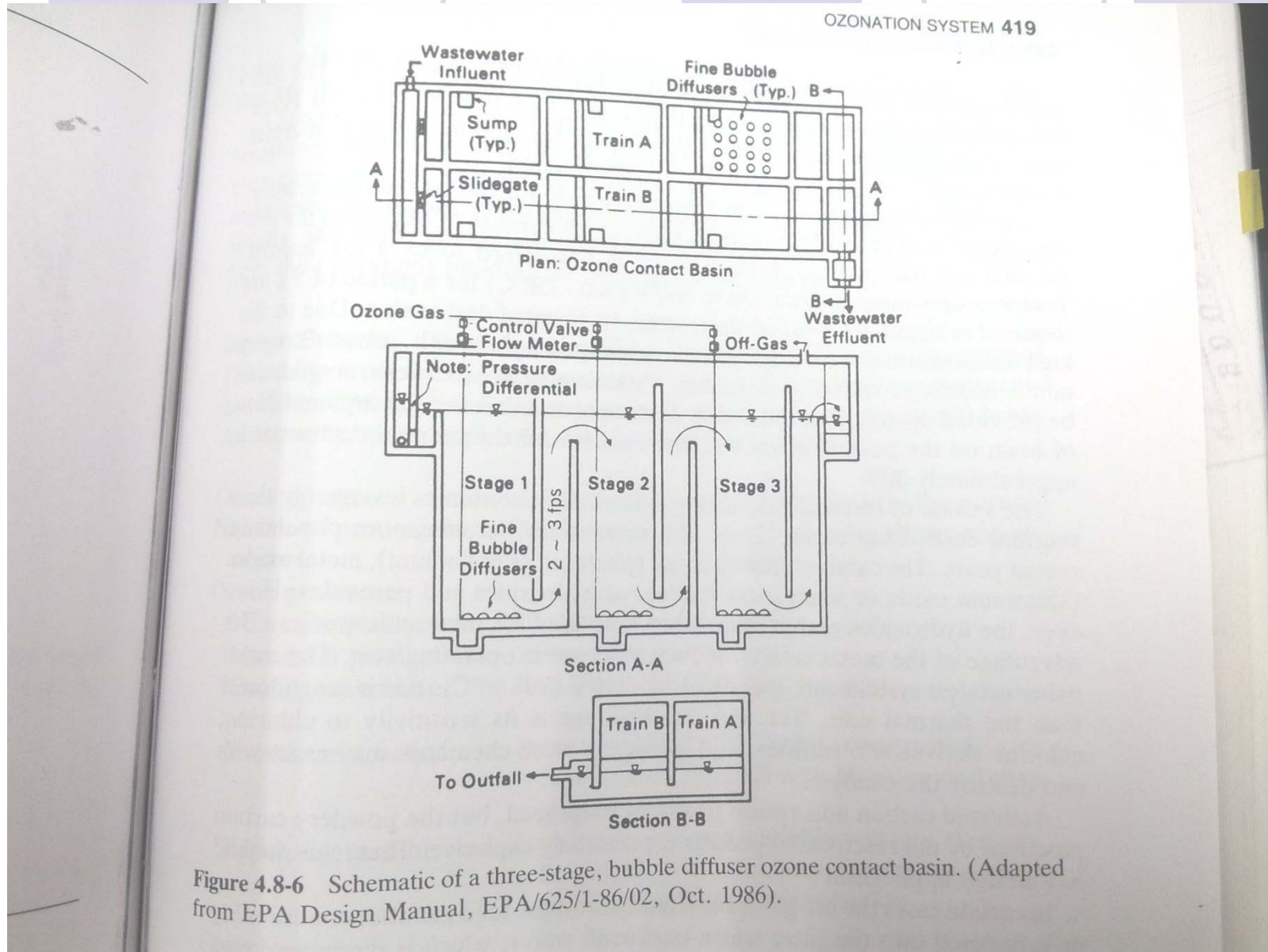


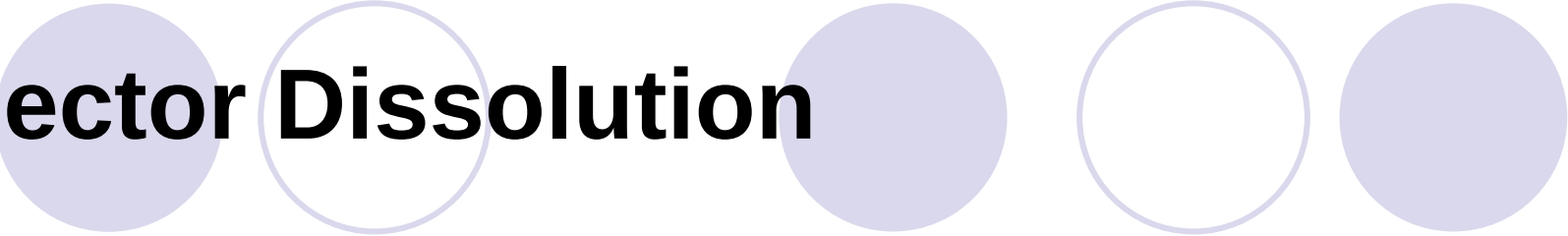
Figure 4.8-6 Schematic of a three-stage, bubble diffuser ozone contact basin. (Adapted from EPA Design Manual, EPA/625/1-86/02, Oct. 1986).

Bubble Diffuser Contactors

Table 3-4. Bubble Diffuser Contactor Advantages and Disadvantages

Advantages	Disadvantages
No moving parts	Deep contact basins
Effective ozone transfer	Vertical channeling of bubbles
Low hydraulic headloss	Maintenance of gaskets and piping.
Operational simplicity	

Injector Dissolution



- The injector contacting method is commonly used in Europe, Canada, and the United States (Langlais et al., 1991).
- Ozone is injected into a water stream under negative pressure, which is generated in a venturi section, pulling the ozone into the water stream.
- In many cases, a sidestream of the total flow is pumped to a higher pressure to increase the available vacuum for ozone injection. After the ozone is injected into this sidestream, the sidestream containing all the added ozone is combined with the remainder of the plant flow under high turbulence to enhance dispersion of ozone into the water.

Injector Dissolution

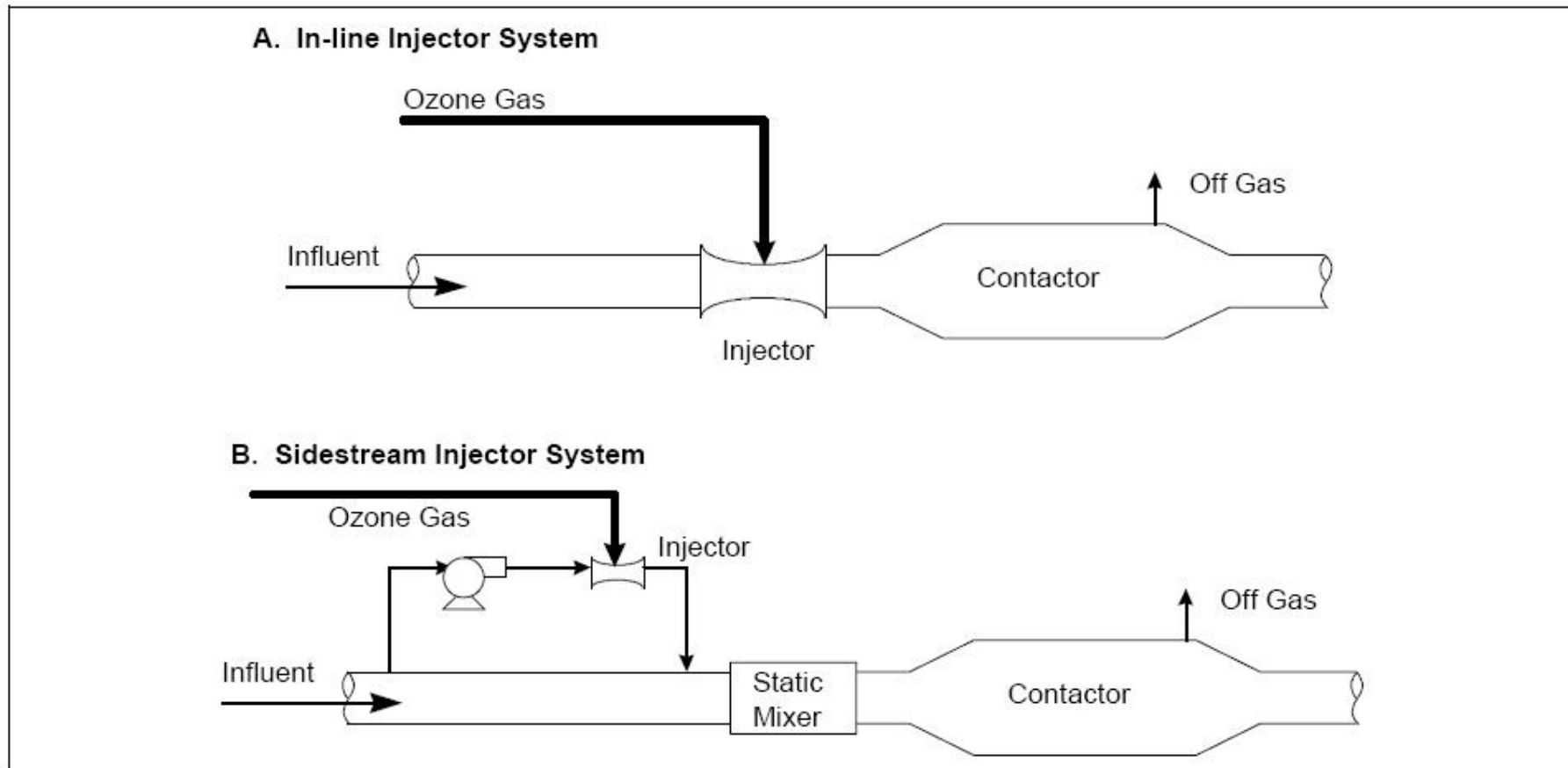


Figure 3-8. Sidestream Ozone Injection System

Injector Dissolution

- Table 3-5 summarizes the advantages and disadvantages of injection contacting (Langlais et al., 1991).

Table 3-5. Injection Contacting Advantages and Disadvantages

Advantages	Disadvantages
Injection and static mixing have no moving parts	Additional headloss (energy usage) due to static mixers which may require pumping
Very effective ozone transfer	Turndown capability limited by injection system
Contactor depth less than bubble diffusion	More complex operation and high cost.

Off-Gas Destruction

- The ozone contact tank typically has a 90-95% transfer of ozone to the water, the remaining 5-10% result as off-gas.
- The ozone content of this off-gas must be reduced to levels below the OSHA and local Air Quality Management District(AQMD) standards prior to venting into the atmosphere.
- According to OSHA, the maximum allowable ambient concentration of ozone is 0.0002 g/m^3 (0.1 ppm by volume) for an 8 hr working day.
- The off-gas normally contains levels greater than 1 g/m^3 (500 ppm by volume).
- Three basic methods of destruction have been used: thermal destruction, thermal destruction with a catalyst, and catalytic destruction.

Safety



- The issue of safety must be addressed because ozone is both a toxic gas and a fire hazard. Moreover, if the system uses oxygen as the feed gas, the situation becomes more dangerous.
- Although the ozonation system may be less hazardous than the chlorination system because it can be shut down if an ozone leak develops, it may also be more dangerous because the system must use high-voltage electrical power to generate the ozone.

Safety(2)



- The American Industrial Hygiene Association(AIHA), OSHA, and other associations recommend the following permissible levels of ozone in the air:
 - Workers will not be exposed to ozone concentrations in excess of a time weighted average of 0.2 mg/m³ (0.1 ppm by volume) for eight hours or more per workday, and that no worker be exposed to a ceiling concentration of ozone in excess of 0.6 mg/m³ (0.3 ppm by volume) for more than 10 minutes
- Local Air Quality Management Districts may have more stringent criteria that are part of the restrictions on smog.
- Other safety considerations:
 - Installation of self-contained breathing apparatuses in the event of a severe ozone leak,
 - Installation of eyewashes and emergency shower
 - Comprehensive safety and operation and maintenance manuals
- Ideally, the ozone generation building and ozone contact tanks are isolated from the operations building for obvious safety reasons

Design Criteria



- The design criteria for the Ozonation system are numerous. They range from the ozone generator, to the contact tank, to the destruction unit. The requirements for these and many more issues are...

Design Criteria

Ozone dosage	1.5 - 3 mg/L(normal) depending on the purpose
Number of ozone generators	Minimum of two, and preferably three; one always acts as a standby
Ozone generator	
Minimum production	10-20% of rated capacity
Maximum production	75% of rated capacity
Cooling water temperature	Less than 75F(24C) at the inlet
Vessel construction	Pressure vessel (15 psig) constructed with 304 LSS or 315 LSS with Hypalon or Teflon gaskets
Type of generator	Low frequency with variable voltage, medium frequency with frequency control, or another type, depending on the selection
Compressor	
Pressure	10-40 psig if heat reactive desiccant; 80-100 psig if pressure swing type desiccant
Number	Minimum of two; one acts as standby
Type	Liquid ring(<1000 lb/day ozone production),
	Centrifugal(>1000 lb/day ozone production),
	Piston type, oil-free, or oil lubricated with oil removal filters(<100 lb/day-small plant)

Design Criteria

Filters	
Before compressor	Regular filter with silencer
Before dryer	3-5 um
Before generator	0.3 um
Pressure drop	0.5 psi when clean, 2 psi for coalescing filter
Moisture removal	
Refrigerant dryer	41F(5C) dewpoint (80% removal from air)
Desiccant dryer	-76F(-60C) dewpoint (99.98% removal from air)

Design Criteria

Ozone contact tanks	
Number of tanks	Minimum of two
Transfer efficiency	Minimum of 95% if possible; may range from 90 to 95%
Detention time	5-15 min(usually less than 8 min)
Stage of contact	Normally two to three stages
Water depth	18-20 ft
Submergence of diffuser	16-18 ft
Freeboard	4-6 ft to allow the deposition of foam

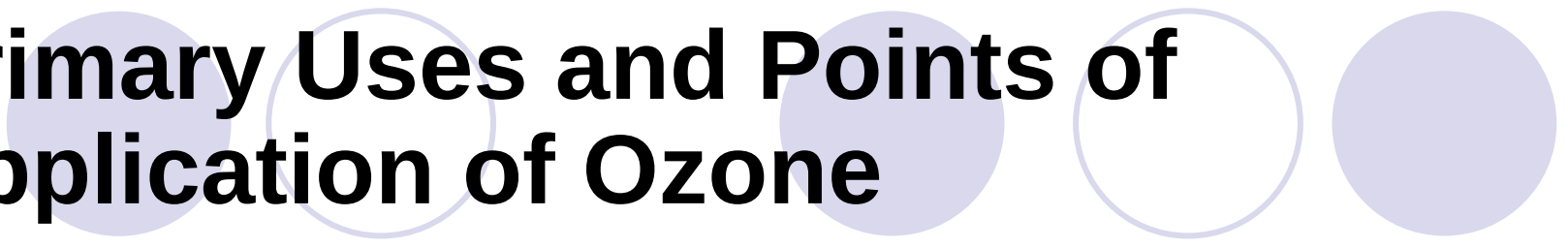
Design Criteria

Ozone diffuser	
Material	304 LSS, glass, ceramic, or Teflon
Bubble size	2-5 mm
Gas flow	0.5 - 4 cfm depending on the diffuser:
(each difuser)	Rod diffuser (2.5 in. x 24 in. L): 4 cfm maximum
	Disk difuser (7 in. diameter): 1.25 cfm maximum
	Disk difuser (9 in. diameter): 1.8 cfm maximum
Headloss	Maximum of 0.5 psi
Permeability	8-20 cfm/ft ²
Porosity	35-45%
Residual ozone (ozonated water)	UV ozone monitor (continuous monitoring)
monitoring Type	such as PCI Model HC or potassium iodide monitoring

Design Criteria

Ozone destruction unit	
Type	Heat catalyst unit (most popular)
Temperature	80 - 100 F (27 - 38 C)
Catalyst	Metal (platinum) or metal oxides: these catalysts are proprietary items

Primary Uses and Points of Application of Ozone



- Ozone is used in drinking water treatment for a variety of purposes including:
 - Disinfection;
 - Inorganic pollutant oxidation, including iron, manganese, and sulfide;
 - Organic micropollutant oxidation, including taste and odor compounds, phenolic pollutants, and some pesticides; and
 - Organic macropollutant oxidation, including color removal, increasing the biodegradability of organic compounds, DBP precursor control, and reduction of chlorine demand.

Disinfection



- Ozone is a powerful oxidant able to achieve disinfection with less contact time and concentration than all weaker disinfectants, such as chlorine, chlorine dioxide, and monochloramine (Demers and Renner, 1992).
- However, ozone can only be used as a primary disinfectant since it cannot maintain a residual in the distribution system.
- Thus, ozone disinfection should be coupled with a secondary disinfectant, such as chlorine, chloramine, or chlorine dioxide for a complete disinfection system.

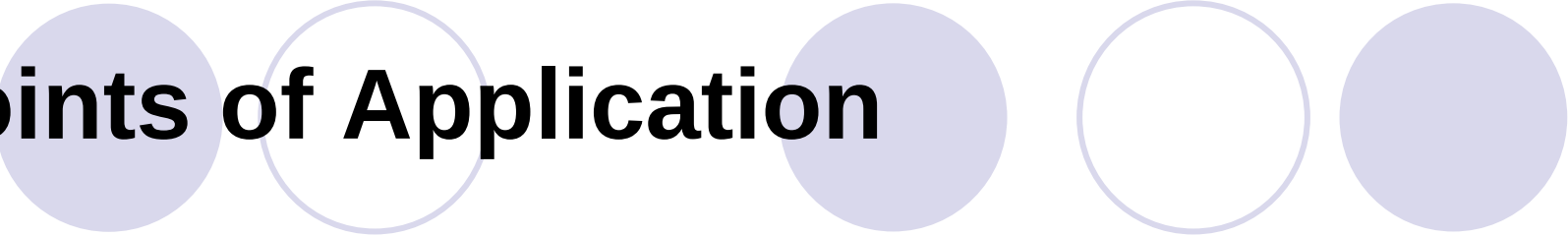
Iron and Manganese Oxidation

- Ozone will oxidize iron and manganese, converting ferrous ($2+$) iron into the ferric ($3+$) state and $2+$ manganese to the $4+$ state. The oxidized forms will precipitate as ferric hydroxide and manganese hydroxide (AWWA, 1990). The precise chemical composition of the precipitate will depend on the nature of the water, temperature, and pH.
- The ozone dose required for oxidation is 0.43 mg/mg iron and 0.88 mg/mg manganese (Langlais et al., 1991). Iron oxidizes at a pH of $6-9$ but manganese is more effective at a pH of around 8 . Also, over-ozonation has no effect on iron, but will resolubilize manganese, which then should be reduced to manganese dioxide downstream.

Oxidation of Taste and Odor Compounds

- Ozone is used to oxidize/destroy taste and odor-causing compounds because many of these compounds are very resistant to oxidation.
- Suffet et al. (1986) confirmed that ozone is an effective oxidant for use in taste and odor treatment. They found ozone doses of 2.5 to 2.7 mg/L and 10 minutes of contact time (ozone residual of 0.2 mg/L) significantly reduced taste and odors in the specific waters they tested.
- Most early U.S. water plants (i.e., 1940-1986) installed ozonation specifically for taste and odor removal.

Points of Application



- The typical locations for feeding ozone in a water treatment plant are at the head of the treatment plant (raw water) pre-ozonation and after sedimentation.
- Raw water quality and turbidity and ozone demand (the amount of ozone required for all oxidation requirements of the water) can be used to assess how to use ozone in the treatment process.
- Table 3-7 lists the criteria for selecting ozone feed points based on these two parameters.
- By moving the ozonation process further downstream after sedimentation, the ozone demand and production of byproducts are reduced. The advantage of placing ozone ahead of filtration is that biodegradable organics produced during ozonation can be removed by subsequent biological activity in the filters.

Points of Application

Table 3-7. Criteria for Selecting Ozone Feed Points for Small Systems

Raw Water Quality	Ozone Feed Point(s)	Special Considerations
Category I Turbidity < 10 NTU Ozone Demand < 1mg/L	Raw Water or After Sedimentation	Low ozone demand. Low disinfection byproducts. Low biodegradable organics.
Category II Turbidity > 10 NTU Ozone Demand < 1mg/L	After Sedimentation Cat II: Presence of inorganic material, such as clay or silt particles	Low ozone demand. High inorganic particulate. Low biodegradable organics.
Category III Turbidity < 10 NTU Ozone Demand > 1mg/L	Raw Water and/or After Sedimentation Cat III: Contains dissolved constituents, not suspended, that contribute to a high ozone demand. Ex. Groundwater	High ozone demand Disinfection byproducts Biodegradable organics formation
Category IV Turbidity > 10 NTU Ozone Demand > 1mg/L	After Sedimentation and After First Stage Filtration, if necessary Cat IV: The most difficult water to treat with ozone due to its high turbidity and high ozone demand. Ex. Surface water containing high concentrations of organic material and inorganic particles.	High ozone demand Disinfection byproducts Biodegradable organics formation

Source: DeMers and Renner, 1992.

Ozonation Disinfection Byproducts

- Ozone does not form halogenated DBPs (TTHMs and HAA₅s) when participating in oxidation/reduction reactions with NOM but it does form a variety of organic and inorganic byproducts.
- Table 3-9 and Figure 3-11 show the principal known byproducts associated with ozonation.
- However, if bromide ion is present in the raw water halogenated DBPs may be formed. These brominated DBPs appear to pose a greater health risk than non-brominated DBPs.

Ozonation Disinfection Byproducts

- Although ozone is an effective oxidant and disinfectant, it should not be relied upon as a secondary disinfectant to maintain a residual in the distribution system.
- Monochloramine is attractive for this purpose because it produces little to no halogenated DBPs.
- Chlorine is a candidate for secondary disinfectant but the ozonated water may actually produce either more or less DBPs following the addition of free chlorine depending on the nature of the organic material following ozonation unless biologically active filtration precedes the addition of chlorine.
- The principal benefit of using ozone for controlling DBP formation is that it allows free chlorine to be applied later in the treatment process after precursors have been removed and at lower doses, thereby reducing DBPFP.

Ozonation Disinfection Byproducts

Table 3-9. Principal Known Byproducts of Ozonation

Disinfectant Byproducts	
Aldehydes	Aldo- and Ketoacids
Formaldehyde	Pyruvic acid
Acetaldehyde	Brominated Byproducts*
Glyoxal	Bromate ion
Methyl Glyoxal	Bromoform
Acids	Brominated acetic acids
Oxalic acid	Bromopicrin
Succinic acid	Brominated acetonitriles
Formic acid	Others
Acetic acid	Hydrogen peroxide

*Brominated byproducts are produced only in waters containing bromide ion

Source: Singer, 1992.

Ozonation Disinfection Byproducts

- Ozonation of a source water containing bromide ion can produce brominated byproducts, the brominated analogues of the chlorinated DBPs. Song et al. (1997) found that bromate ion formation is an important consideration for waters containing more than 0.10 mg/L bromide ion. These brominated byproducts include bromate ion, bromoform, the brominated acetic acids and acetonitriles, bromopicrin, and cyanogen bromide (if ammonia is present). An ozone dose of 2 mg/L produced 53 mg/L of bromoform and 17 mg/L of dibromoacetic acid in a water containing 2 mg/L of bromide ion (McGuire et al., 1990). Ozonation of the same water spiked with 2 mg/L bromide ion showed cyanogen bromide formation of 10 mg/L (McGuire et al., 1990). Furthermore, ozone may react with the hypobromite ion to form bromate ion (Amy and Siddiqui, 1991; Krasner et al., 1993), a probable human carcinogen (Regli et al., 1992). Bromate ion concentrations in ozonated water up to 60 mg/L have been reported (Amy and Siddiqui, 1991; Krasner et al., 1993). Note that the amount of bromide ion incorporated into the measured DBPs accounts for only one-third of the total raw water bromide ion concentration. This indicates that other brominated DBPs exist that are not yet identified (Krasner et al., 1989; MWDSC and JMM, 1992). Figure 3-12 shows the major pathways for bromate ion formation.

Operational Considerations: Process Considerations

- Because ozone is such a strong oxidant, it will react with many organic and inorganic compounds present in the water.
- Ozone is used to remove tastes and odors by breaking down organic compounds, and to aid in the removal of iron and manganese by oxidizing these compounds to less soluble forms. These demands should be satisfied before any ozone is available to satisfy primary disinfection requirements. The presence and concentration of these compounds can dictate the location of ozone addition, depending on the process goals.

Operational Considerations: Space Requirements

- Storage of LOX is subject to regulations in building and fire codes. These regulations will impact the space requirements and may dictate the construction materials of adjacent structures if the certain setback requirements cannot be met.
- In general, the footprint for ozone generated from air is smaller than that required for chloramination and chloride dioxide applications.
- However, the footprint area for ozone generated from pure oxygen is comparable to that of chlorine dioxide because of the additional area needed for storage.

Operational Considerations: Material Selection

- Ozone-resistant materials should be used from the ozone generators through the off-gas destruct unit.
- If oxygen is used for the feed gas, oxygen resistant materials should be used up to the generators.
- Pure oxygen piping should be specially cleaned after installation for oxygen service, which increases construction cost.
- Materials for air preparation systems can be those normally used for compressed air systems.
- Langlais et al. (1991) recommended that piping beyond the desiccant dryers be ozoneresistant, as some backflow and ozone diffusion can occur.
- If a receiver is provided following the desiccant dryer, the piping should be ozone-resistant, downstream of the pressure regulator. Ozoneresistant (oxygen resistant as well if high purity oxygen is the feed gas) check valves should be placed in the piping ahead of the generator.

Operational Considerations: Material Selection(2)

- Ozone-resistant materials include the austenitic (300 series) stainless steels, glass and other ceramics, Teflon and Hypalon, and concrete. The 304 series stainless steels can be used for “dry” ozone gas (also for oxygen), 316 series should be used for “wet” service. Wet service includes piping in the contactors and all off-gas piping and the off-gas destruct unit. Teflon or Hypalon should be used for gasket materials. Concrete should be manufactured from Type II or Type IV cement.
- Typical practice in the United States is to provide 3 inches of cover for reinforcing to prevent corrosion by either ozone gas or ozone in solution, although Fonlupt (1979) reports that 4 cm (1.13 inches) is adequate for protection. Hatches for access into contactors should be fabricated from 316 series stainless steels and provided with ozone-resistant seals.

Operational Considerations: Ozone System Maintenance

- Stolarik and Christie (1997) provide a good overview of the operational and maintenance requirements during the 10 years of operating the 600 mgd Los Angeles Aqueduct Filtration and Ozone Plant.
- The ozone system has been available 97.1 percent of the time over the 10 year period.
- Fuse failure and generator cleaning comprised the major maintenance chores on the ozone generators during the first years. Fuse failure was caused by a malfunction when its glass dielectric tube failed.
- Vessels are cleaned every three years or when exit gas temperatures rise due to Fe_3O_4 deposits on the ground electrode/heat exchanger surfaces.
- Rod shaped ceramic diffusers worked well as ozone diffusers for the initial two years. These were replaced by sintered stainless steel and ultimately a modified ceramic diffuser.

Ozone Safety



- Concern for safety even at the risk of being overcautious, would be to follow practices that have been successfully applied to other oxidants over the years.
- This would be to generally isolate the ozonation system from the remainder of the plant. This should not be interpreted to mean a separate building, but rather separate rooms, separate exterior entrances, separate heating and ventilation systems, noise control, etc. This method already is manifested in some of the European ozonation plants, but on a lesser scale.

Ozone Safety



- Ozone generators should be housed indoors for protection from the environment and to protect personnel from leaking ozone in the case of a malfunction.
- Ventilation should be provided to prevent excess temperature rise in the generator room, and to exhaust the room in the case of a leak.
- Adequate space should be provided to remove the tubes from the generator shell and to service the generator power supplies. Air prep systems tend to be noisy; therefore, it is desirable to separate them from the ozone generators.
- Off-gas destruct units can be located outside if the climate is not too extreme. If placed inside, an ambient ozone detector should be provided in the enclosure.
- All rooms should be properly ventilated, heated, and cooled to match the equipment-operating environment.

Ozone Safety

- Continuous monitoring instruments should be maintained to monitor levels of ozone in the rooms.
- Self-contained breathing apparatuses should be located in hallways outside the rooms liable to ozone hazards. Ambient ozone exposure levels, which have been proposed by appropriate U.S. organizations, are summarized below.
- The maximum recommended ozone levels are as follows:
- **Occupational Safety and Health Administration.** The maximum permissible exposure to airborne concentrations of ozone not in excess of 0.1 mg/L (by volume) averaged over an eight hour work shift.
- **American National Standards Institute/American Society for testing Materials (ANSI/ASTM).** Control occupational exposure such that the worker will not be exposed to ozone concentrations in excess of a time weighted average of 0.1 mg/L (by volume) for eight hours or more per workday, and that no worker be exposed to a ceiling concentration of ozone in excess of 0.3 mg/L (by volume) for more than ten minutes.
- **American Conference of Government Industrial Hygienists (ACGIH).** Maximum ozone level of 0.1 mg/L (by volume) for a normal eight hour work day or 40 hour work week, and a maximum concentration of 0.3 mg/L (by volume) for exposure of up to 15 minutes.
- **American Industrial Hygiene Association.** Maximum, concentration for eight hour exposure of 0.1 mg/L (by volume).

Ozone Safety

- There is a question of whether prolonged exposure to ozone may impair a worker's ability to smell or be aware of ozone levels at less than critical levels. Awareness of an odor of ozone should not be relied upon.
- Instrumentation and equipment should be provided to measure ambient ozone levels and perform the following safety functions:
 - Initiate an alarm signal at an ambient ozone level of 0.1 mg/L (by volume). Alarms should include warning lights in the main control panel and at entrances to the ozonation facilities as well as audible alarms.
 - Initiate a second alarm signal at ambient ozone levels of 0.3 mg/L (by volume). This signal would immediately shut down ozone generation equipment and would initiate a second set of visual and audible alarms at the control panel and at the ozone generation facility entrances.
- An emergency ventilation system capable of exhausting the room within a period of 2 to 3 minutes
- also would be interconnected to the 0.3 mg/L ozone level alarm.

Ozone Safety



- Ozone gas is a hazardous gas and should be handled accordingly. Ambient ozone levels should be monitored and equipment shut-down and alarmed when levels exceed 0.1 ppm.
- Emergency ventilation is typically provided for enclosed areas.
- Building and fire codes will provide additional guidance.
- The OSHA exposure limit for an 8-hour shift is 0.1 ppm by volume.
- The pungent odor of ozone will provide warning to operators of any possible ozone leak.

Summary: Advantages and Disadvantages of Ozone Use

- **Advantages**

- Ozone is more effective than chlorine, chloramines, and chlorine dioxide for inactivation of viruses, *Cryptosporidium*, and *Giardia*.
- Ozone oxidizes iron, manganese, and sulfides.
- Ozone can sometimes enhance the clarification process and turbidity removal.
- Ozone controls color, taste, and odors.
- One of the most efficient chemical disinfectants, ozone requires a very short contact time.
- In the absence of bromide, halogen-substitutes DBPs are not formed.
- Upon decomposition, the only residual is dissolved oxygen.
- Biocidal activity is not influenced by pH.

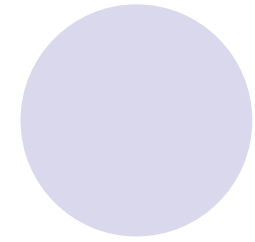
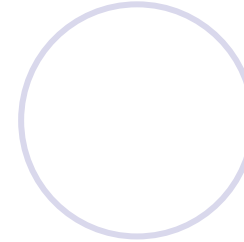
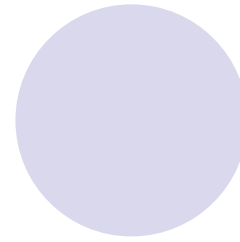
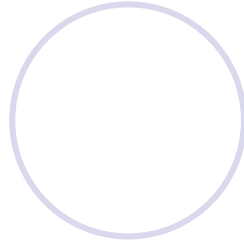
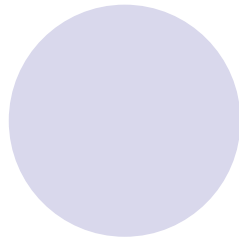
Summary: Advantages and Disadvantages of Ozone Use

- **Disadvantages**

- DBPs are formed, particularly by bromate and bromine-substituted DBPs, in the presence of bromide, aldehydes, ketones, etc.
- The initial cost of ozonation equipment is high.
- The generation of ozone requires high energy and should be generated on-site.
- Ozone is highly corrosive and toxic.
- Biologically activated filters are needed for removing assimilable organic carbon and biodegradable DBPs.
- Ozone decays rapidly at high pH and warm temperatures.
- Ozone provides no residual.
- Ozone requires higher level of maintenance and operator skill.

Table 3-12. Summary of Ozone Disinfection Considerations

Consideration	Description
Generation	Because of its instability, ozone should be generated at the point of use. Ozone can be generated from oxygen present in air or high purity oxygen. The feed gas source should be clean and dry, with a maximum dewpoint of -60°C. Ozone generation consumes power at a rate of 8 to 17 kWhr/kg O ₃ . Onsite generation saves a lot of storage space.
Primary uses	Primary uses include primary disinfection and chemical oxidation. As an oxidizing agent, ozone can be used to increase the biodegradability of organic compounds destroys taste and odor control, and reduce levels of chlorination DBP precursors. Ozone should not be used for secondary disinfection because it is highly reactive and does not maintain an appreciable residual level for the length of time desired in the distribution system.
Inactivation efficiency	Ozone is one of the most potent and effective germicide used in water treatment. It is effective against bacteria, viruses, and protozoan cysts. Inactivation efficiency for bacteria and viruses is not affected by pH; at pH levels between 6 and 9. As water temperature increases, ozone disinfection efficiency increases.
Byproduct formation	Ozone itself does not form halogenated DBPs; however, if bromide ion is present in the raw water or if chlorine is added as a secondary disinfectant, halogenated DBPs, including bromate ion may be formed. Other ozonation byproducts include organic acids and aldehydes.



Byproduct formation

Ozone itself does not form halogenated DBPs; however, if bromide ion is present in the raw water or if chlorine is added as a secondary disinfectant, halogenated DBPs, including bromate ion may be formed. Other ozonation byproducts include organic acids and aldehydes.

Limitations

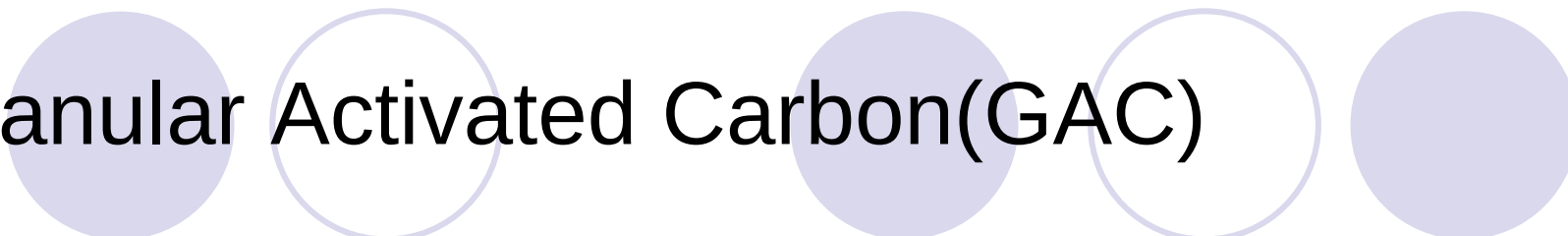
Ozone generation is a relatively complex process. Storage of LOX (if oxygen is to be the feed gas) is subject to building and fire codes.

Points of application

For primary disinfection, ozone addition should be prior to biofiltration/filtration and after sedimentation. For oxidation, ozone addition can be prior to coagulation/sedimentation or filtration depending on the constituents to be oxidized.

Safety considerations

Ozone is a toxic gas and the ozone production and application facilities should be designed to generate, apply, and control this gas, so as to protect plant personnel. Ambient ozone levels in plant facilities should be monitored continuously.

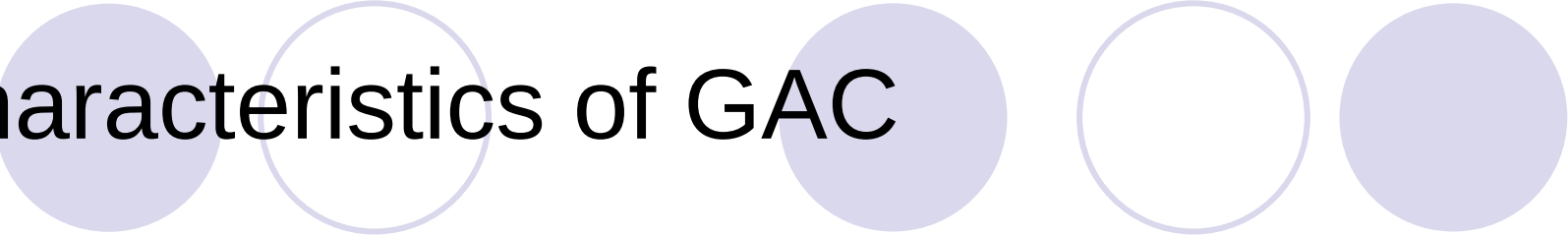


Granular Activated Carbon(GAC)

● Facts & purpose

- Used as a substitute for granular filter medium
- Used as an additional process in the conventional treatment process, for the removal of organic compounds, including disinfection by products, those producing taste and odor, pesticides, and other synthetic organic compounds.
- ++ Has been proved to be effectively in removing these various organic compounds and even organic mercury
- ++ Not only capable of functioning in the same manner as ordinary filters-removal of suspended matter but also removes organic compounds.

Characteristics of GAC

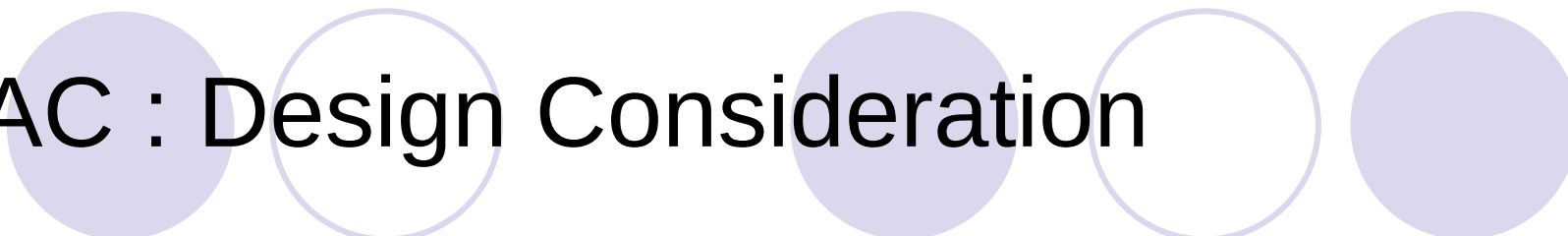


- GAC may be manufactured from a variety of materials: wood, nut shells, coal, peat, or petroleum residues.
- GAC used in water treatment is usually produced from bituminous or lignite coal through slow furnace heating under anaerobic conditions. The absence of oxygen ensures that the coal does not burn but transformed into a porous carbon material.

GAC

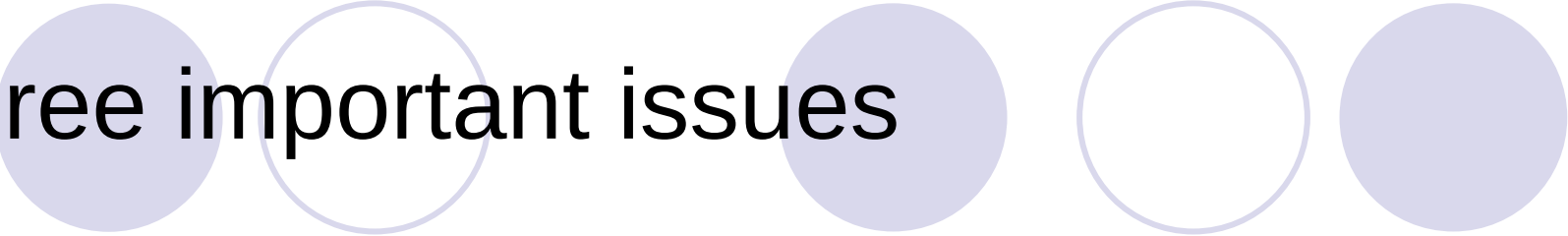
- According to the Calgon Bulletin, the physical properties of GAC are as follows:

○ Total surface area of GAC	890 – 900 m ² /g
○ Bulk density of wetter GAC	30 lb/ft ³
○ Particle density	1.4 – 1.5 g/cm ³
○ Effective size	0.8 – 0.9 mm for Filtrasorb 100 0.55 – 0.65 mm for Filtrasorb 200
○ Uniformity coefficient	1.9 for Filtrasorb 100 1.7 for Filtrasorb 200
○ Iodine Number	850 – 875
○ Abrasion number	70 – 86
○ Moisture as packed	0.5 – 2 %



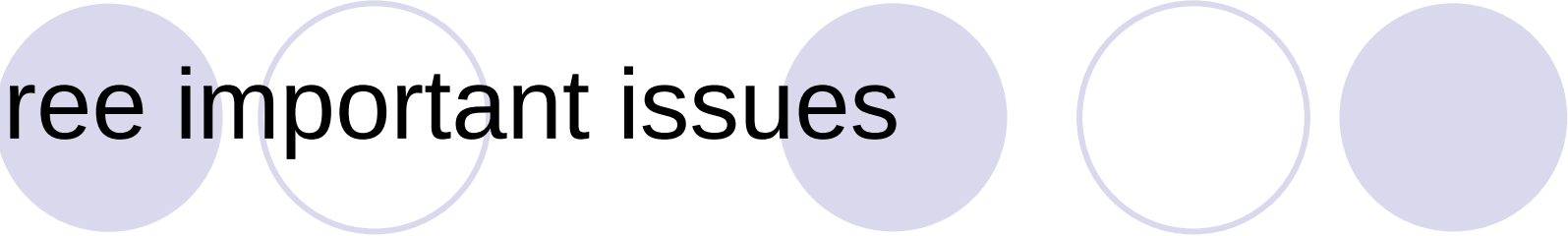
GAC : Design Consideration

- The major design considerations of the GAC contactors are:
 - The designed flow rate and available headloss for this process
 - The nature and amount of all organic compounds in the water supply
 - The MCLs of the regulated organic compounds
 - The overall treatment process train and each unit process
 - The type of GAC
 - The size of the GAC
 - The filtration rate (superficial velocity)
 - The empty bed contact time (EBCT)
 - The type of contact unit
 - The location of the GAC contactor in the process train
 - The regeneration frequency and the method to do it



Three important issues

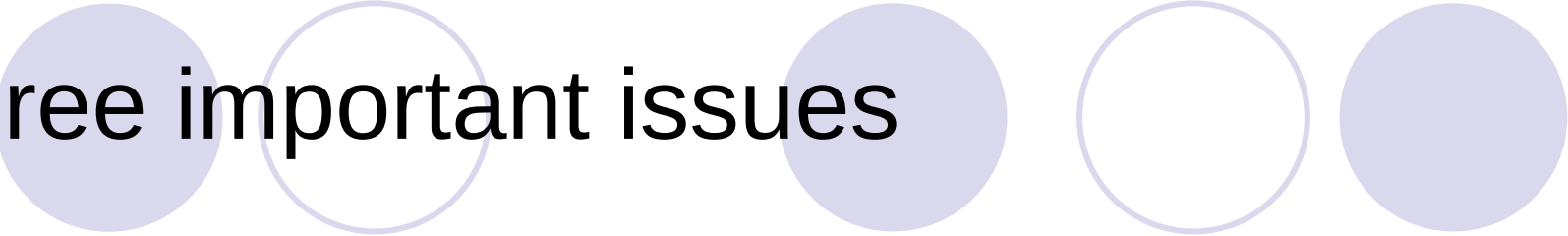
- Select the proper size and specific gravity of GAC so that both GAC bed and sand or anthracite layers are fluidized to the same degree during backwash; that is, both GAC and other types of media in a filter cell must be hydraulically matched during the filter washing period. Otherwise, GAC is either washed out or become dirty and clogged with suspended matter and biomass.



Three important issues

- The second design issue is to provide a proper L/d ratio across the filter bed. Since the filter bed does not act as an adsorption bed but as a filtration and adsorption bed, the turbidity of the filter effluent should be less than 0.1 ntu as a goal.

Three important issues



- The third issue is the size and gradation of the GAC grains. For the adsorption process, GAC of small size and with a high uniformity coefficient is preferable. The filtration process, however, requires a larger size with a small uniformity coefficient; this is essential for the longer filter run and to achieve good effluent quality

GAC

- Modern filter beds, including GAC, are composed of media with an effective size of 1.2 to 1.5 mm, with a uniformity coefficient of less than 1.4, and have a bed depth of 6 to 7 ft.(1.8 to 2.1 m.) with or without a sand barrier at the bottom

GAC

- Size of GAC

- The size of the GAC strongly influences both the depth of the bed and the headloss across the bed given a specific flow rate.
- Coarse GAC has definite advantage for application to deep bed gravity contactors under high filtration rates
- However, smaller sized GAC is characterized by a higher rate of adsorption, given an equal level of activity with shallower bed, since it has a greater active surface area.

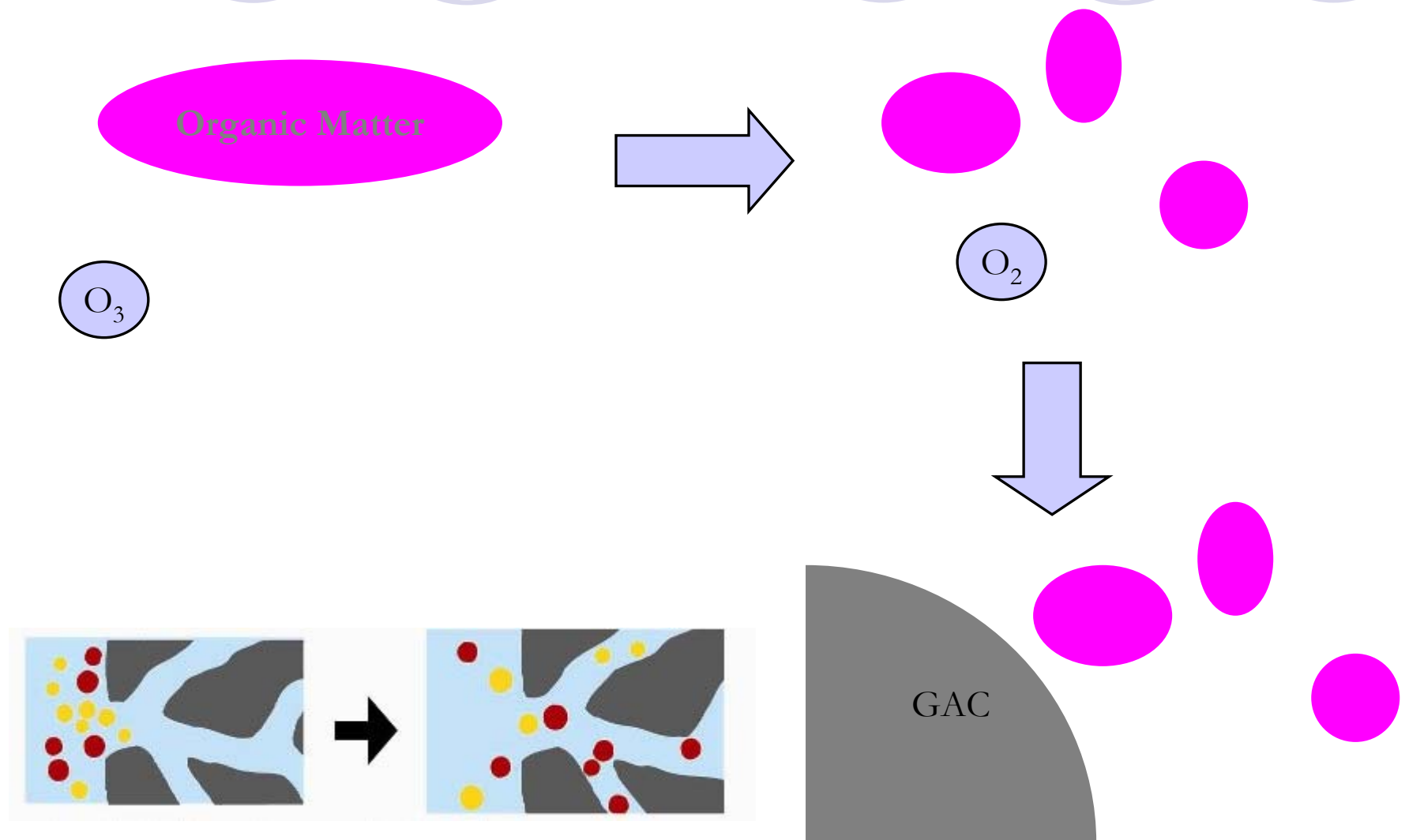
- Filtration rate

- Generally, the most common filtration rate is 2 – 5 gpm/ft²(5 – 12.5 m/h), although higher rates are also used.

- EBCT

- A practical EBCT is one that ranges from 7.5 to 30 min. (Kawamura 1991) or 7.5 to 10 min(Kawamura 2000)
- The shorter EBCT may be used when removing synthetic organic compounds (SOCs) since they are easily adsorbed, but no longer contact time must be used in removing the more soluble and less adsorbable organic compounds.

Ozonation and GAC Adsorption



Ozonation and GAC Criteria

Criteria	JAPAN	KOREA	MWA Propose
Ozonation			
Ozone dosage (mg/l)	2.0 (max.)	2.0	2.5
Ozone : TOC	1:1	NA	1:1
Ozone contact time (min)	7.1-9.5	15.6	10
Oxygen supply	Oxygen generator	Oxygen gas	Oxygen generator
Oxygen generator type	Pressure swing adsorption	Product from industries	Pressure swing adsorption
Mixing type	Diffuser	Side stream injection	Diffuser
Of gas unit	Manganese catalytic	Metal catalyst	Manganese catalytic

Ozonation and GAC Criteria

Criteria	JAPAN	KOREA	MWA Propose
GAC Filter			
Linear velocity (m/h)	12.5-16.2	15	12.5
EBCT (min)	10-11	10	12
Bed depth (m)	2.3-2.7	2.5	2.5



The WTP story from Japan

Osaka Murano WTP

Water Resource / Water Treatment Plants(WTP) of OWSA

Water quality characteristics of the Yodo River

- relatively high THMFP and $\text{NH}_3\text{-N}$
- annual occurrence of musty odor
- accidental raw water contamination



Water supply amount (bulk water)

530 million m^3/year

Municipalities supplied

42 municipalities in Osaka Pref.

Population served

6 million people in Osaka Pref.

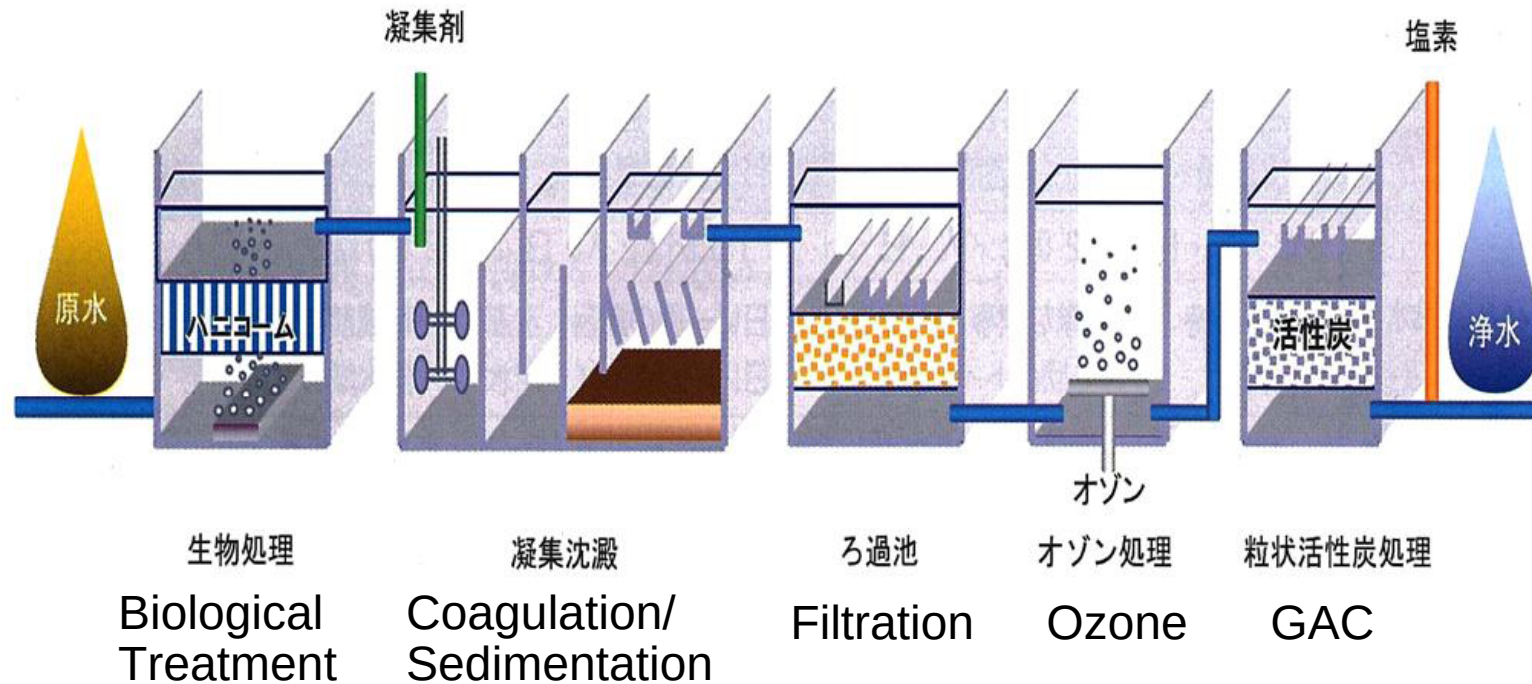
Factors behind Improvement of Water Treatment

- Raw water contamination
 - Contamination by trace organic compounds
 - Musty odor causing compounds (2-MIB, Geosmin)
 - Trihalomethane formation potential (THMFP), etc.
 - Contamination by ammonium nitrogen
 - Frequent accidental raw water contamination
- Increase of consumers' health consciousness
 - Information disclosure
- Strengthening of water quality regulation
 - Progress of analytical technologies
 - Progress of toxicity assessments

Water Treatment Improvement History

- 1955 ~
(powdered AC)—prechlorination—coagulation/sedimentation
—rapid sand filtration—post-chlorination
- 1991 : *Mishima WTP*
biological treatment (contact aeration)
—prechlorination—coagulation/sedimentation—rapid sand filtration
—post-chlorination
- 1994 : *Murano WTP(partly)*, 1998 : *Murano WTP(whole)/Niwakubo WTP*
coagulation/sedimentation—rapid sand filtration
—ozonation—GAC treatment—post-chlorination
- 1998 : *Mishima WTP*
biological treatment—coagulation/sedimentation—rapid sand filtration
—ozonation—GAC treatment—post-chlorination
- 2005 : *Niwakubo WTP*
biological treatment (contact filtration)— dual-layer filtration
—ozonation—GAC treatment—post-chlorination

Typical flow diagram of Advanced Water Treatment in Japan

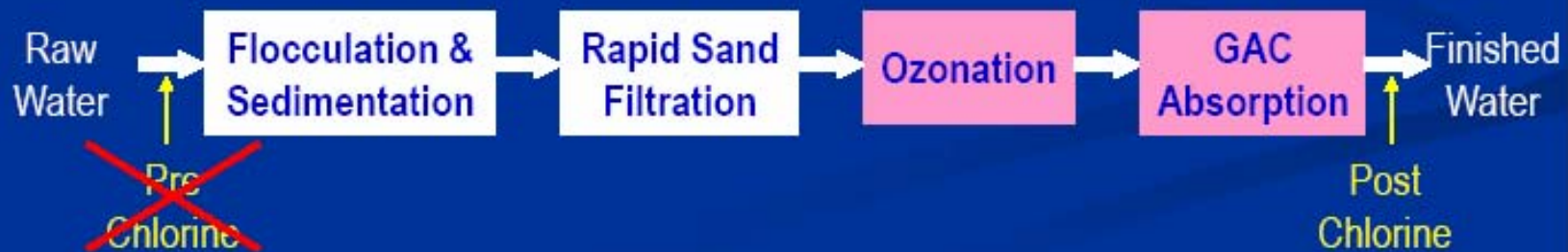


Advanced Water Treatment System in Murano W.T.P

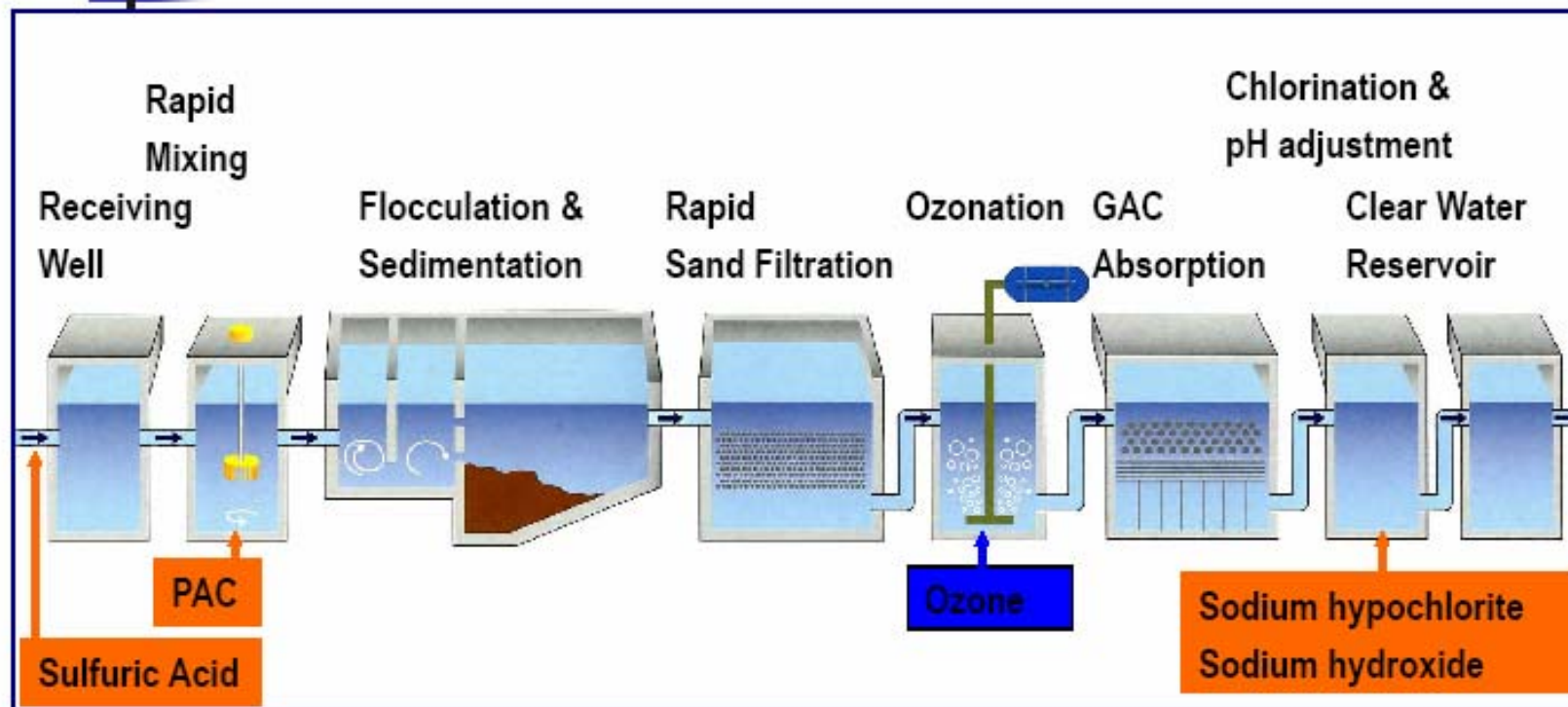
Former System (Conventional Treatment System)



Present System (Advanced Treatment System)



Water Treatment Process



PAC : Poly Aluminum Chloride

GAC : Granular Activated Carbon

Advanced Water Treatment

ถังตกตะกอน โรงงานผลิตน้ำ Murano



Sedimentation Basin E-system

$W \times L \times D = 32.1 \times 24.05 \times 3.4 \text{ (m)}$

Retention time 60 min

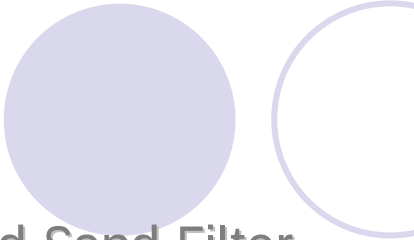


Advanced Water Treatment

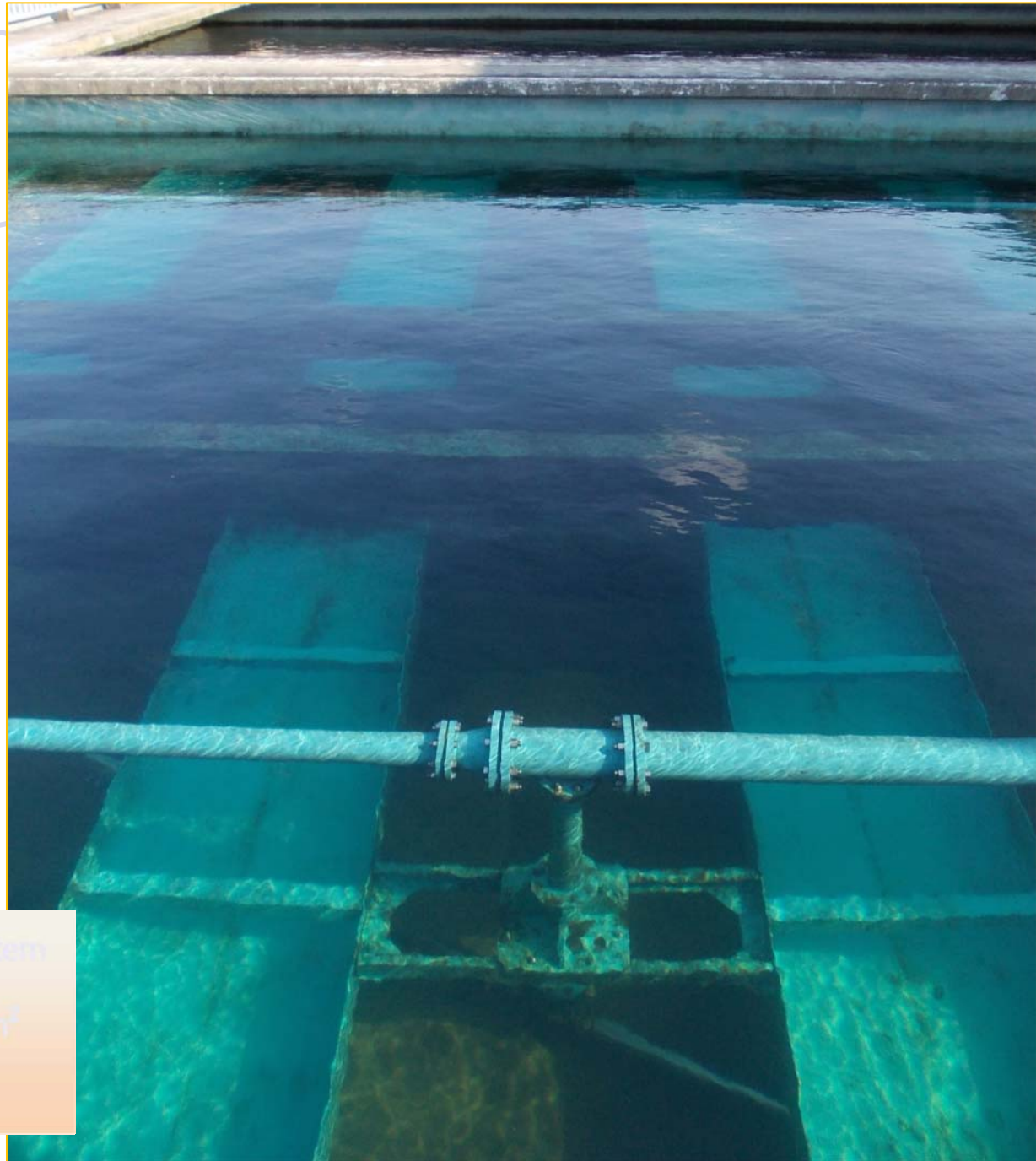


Advanced Water Treatment





Rapid Sand Filter Murano WTP



Rapid sand filtration Basin E-system

Effective filtration area : 168 m²

Filtration rate : 178 m/day

Specifications of Ozone / GAC / Biological Treatment

Ozonation process	
Dosage	maximum 2mg/L
Contact type	Countercurrent, 2- or 3-stage contact
Contact time	7.5~9.5 min
Ozone generation	air-type corona discharge generator
Diffuser	diffuser-type, cylindrical diffuser tube

GAC treatment process	
Flow type	gravity downward flow
Space velocity	approx. 6.0 /hr
Bed depth	1.4~2.7m
Material	coal-based, about 1mm in diameter.

Biological treatment processes	
Contact method	contact aeration by honeycomb type modules submerged 3m in depth, contact time:40min
	contact filtration by spherical-shaped fiber media bed depth:2.0m, space velocity:7.5 /hr

Water Quality Items of Concern in OWSA

Categories	Water quality items	Range of concentrations in OWSA (fiscal 2011)		Regulations for drinking water in Japan (S): standard value (T): target value
		Raw water	Supplied water to municipalities	
Pathogenic microorganisms	Cryptosporidium	ND	—	Turbidity of filtered water to be below 0.1 degree (T)
	Giardia	ND	—	
DBPs	Bromate	< 0.0005mg/L	< 0.0005~0.0026mg/L	≤ 0.01mg/L (S)
Radioactive substances	Gross β activity	ND ¹⁾	ND ^{1), 2)}	— — —
	Iodine-131	—	—	≤ 100Bq/kg (provisional value in emergencies by Food Sanitation Act for infants) ≤ 300Bq/kg (provisional value in emergencies by Nuclear Safety Commission)
	Caesium-134, 137	—	—	≤ 10Bq/kg (T) (long-term health effect)
PPCPs	Pharmaceuticals	0.04~0.05μg/L (1 out of 24)	ND ²⁾	— — —
PFCs	PFOS	0.001~0.005μg/L	0.001~0.008μg/L	No target values (items for further study)
	PFOA	0.009~0.019μg/L	0.008~0.034μg/L	

1) After March 15, 2011

2) At outlets of water treatment plants

Removal Processes

Categories	Water quality items	Removal processes / Control points (●)			Notes
		Pretreatment/ Coagulation/ Sedimentation/ Sand filtration	O ₃	GAC	
Pathogenic microorganisms	Cryptosporidium	●	●	●	• reduced by rapid sand/GAC filtration
	Giardia				• inactivated by ozonation
DBPs	Bromate		●		• controlled by ozone dosage
Radioactive substances	Iodine-131	●			• reduced by pre-chlorination + powdered AC ^{1), 2)}
	Caesium-134, 137	●			• reduced by coagulation/sedimentation ²⁾
PPCPs	Pharmaceuticals		●	●	• oxidized by chlorination, ozonation and removed by GAC treatment, powdered AC dose ^{3), 4)}
PFCs	PFOS			●	• reduced by GAC treatment (depending on duration of GAC use) ⁴⁾ and powdered AC dose
	PFOA			●	• removed by ultraviolet irradiation (under research)

1) National Institute of Public Health

2) Bureau of Waterworks of Tokyo Metropolitan Government

3) National Institute of Health Sciences

4) Osaka Municipal Waterworks Bureau

Specification of Ozonation Facility (W+E Line)

Type of ozone generator	Multiple-cylinder , corona discharge generator
Type of feed gas	Air
Air treatment system	Cooler and dryer
Ozone dosing ratio	Maximum 2 mg/L
Ozone output	27.5 kg/h X 5 units
Ozone concentration	20 g/Nm ³
Volume of ozonized air	1,375/ Nm ³
Contact method	Counter-current 3 stage contact
Contact time	7.5 min
Mixing system	Vertical baffling
Capacity	6,900 m ³ /h per basin
Ozone contact basin	8 basin WxLxD = 11x12.3x6 m
Off-gas destruction	Manganese dioxide catalytic decomposition
Diffuser type	Ceramic cylindrical diffuser tube
Pore diameter	50-60 μm
Total number of diffuser tube	1,440
Power consumption	Max 1,600 kW , Min 500 kW

Specification of GAC Treatment Facility (W+E Line)

Construction	Downflow gravity natural equilibrium system
Space velocity	Approx. 6.0 (1/h)
Linear velocity	Approx. 16.2 (m/h)
Total basin area	Approx. 113.6 m ² X 32 basins Approx.(W) 4.0m x (L) 14.2m x 2
GAC bed depth	2.7m
Type	Coal-base GAC
Granular diameter	Average Approx. 1.0 mm
Hardness	Over 90 (%)
Uniformity coefficient	1.5 – 1.9
Packing density	Over 0.45 (g/ml)
Volume of GAC used	Approx. 9,800 m ³ (W+E Line)
Lower catchment unit	Unit type porous plate system
Washing method	Simultaneous air/water washing
Washing water	Activated-carbon self-treated water
Exhaust ozone treatment	Activated-carbon catalytic cracking method

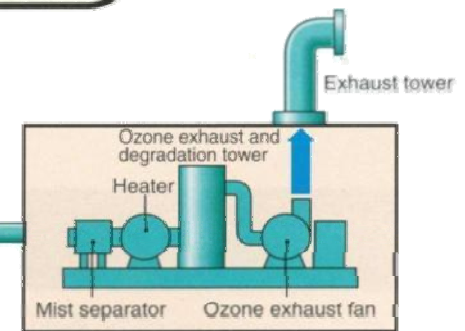
Ozonation

Ozonation

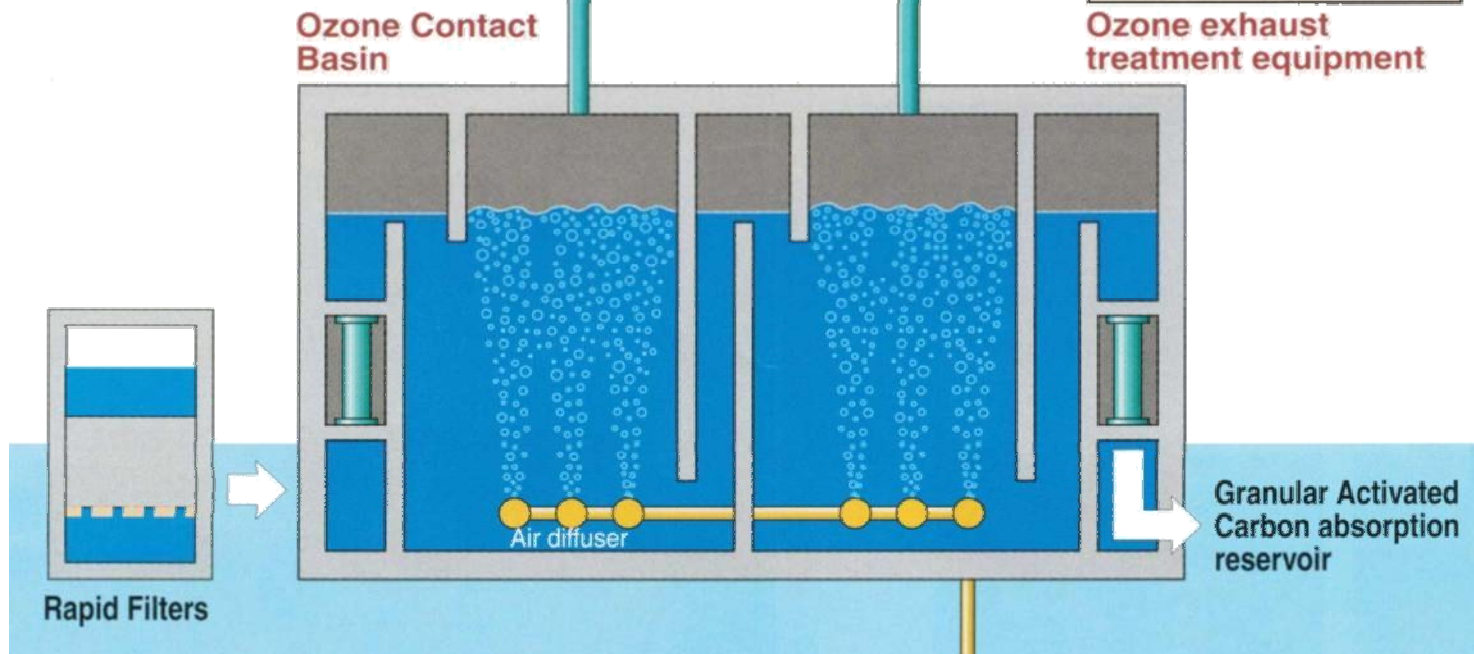
Contact ozone to filtrate water in the ozone contact reservoir to dissolve, deodorize and decolorize mold odor substance and organic microcontaminants by using strong oxidizing power of ozone produced from oxygen in the air.



Ozone generator



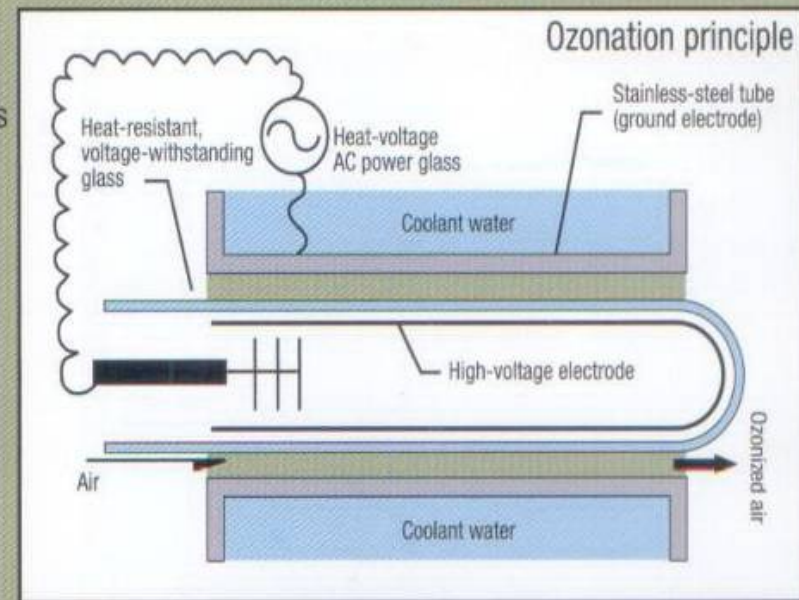
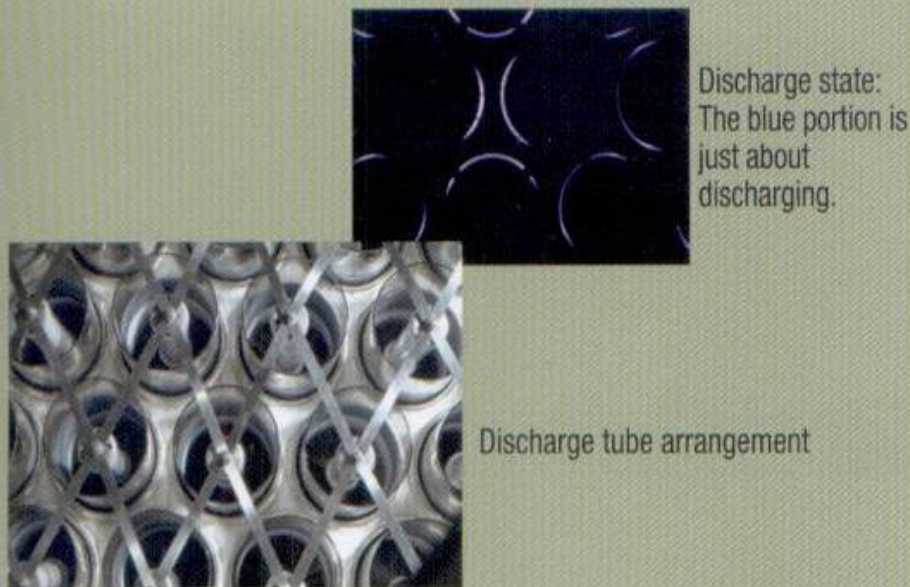
Ozone exhaust treatment equipment



Ozone Generator: Osaka Murano WTP



Ozone Generator: Osaka Murano WTP



A corona discharge is generated when a high-voltage alternating current is applied between electrodes separated by a dielectric. When oxygen containing gas passes through the discharge gap, the discharge energy changes some of the dissociated or excited oxygen to ozone.

Ozonation principle

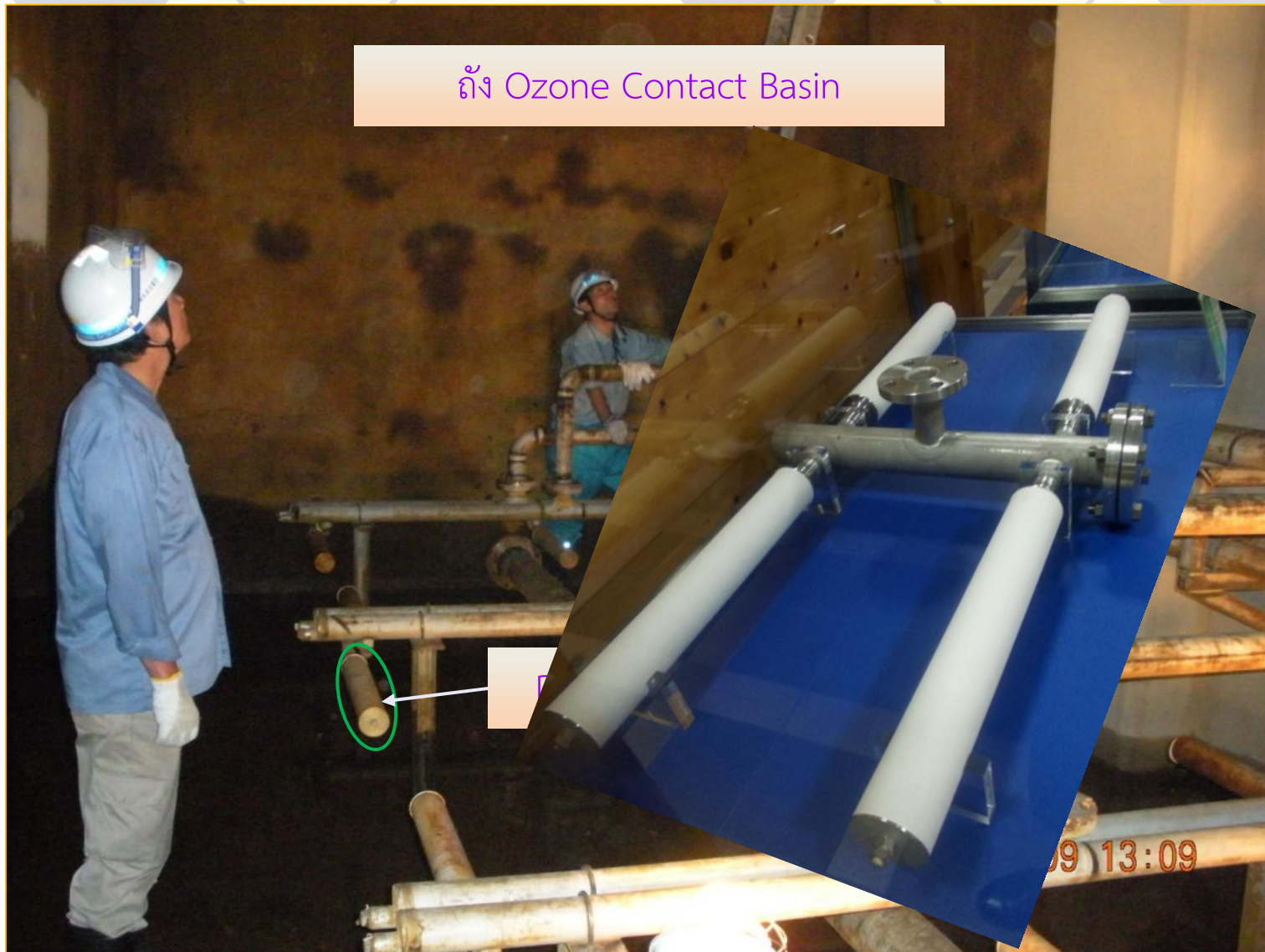
Ozonation

ถัง Ozone Contact Basin



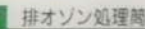
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Ozonation



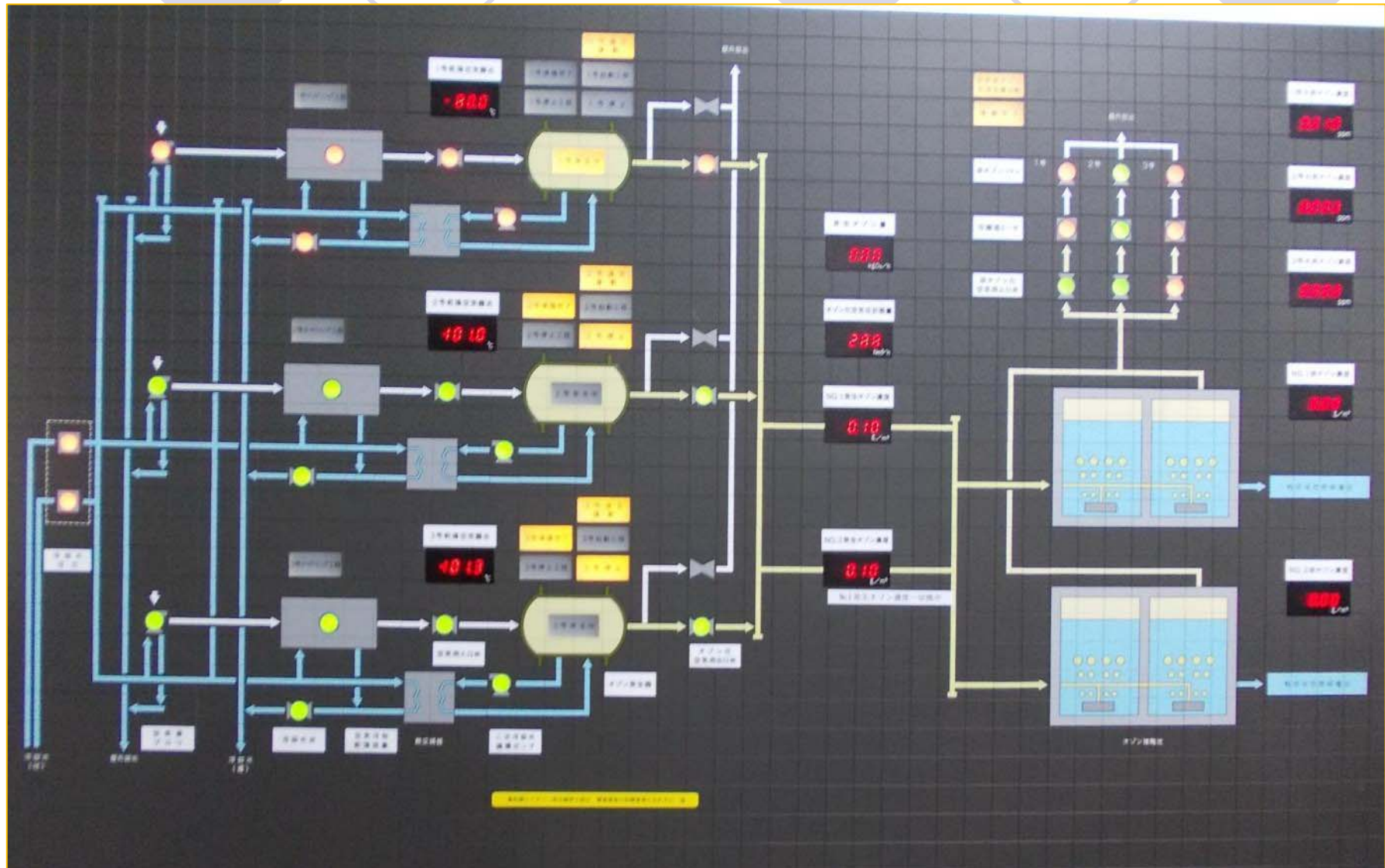
排臭ガス処理機

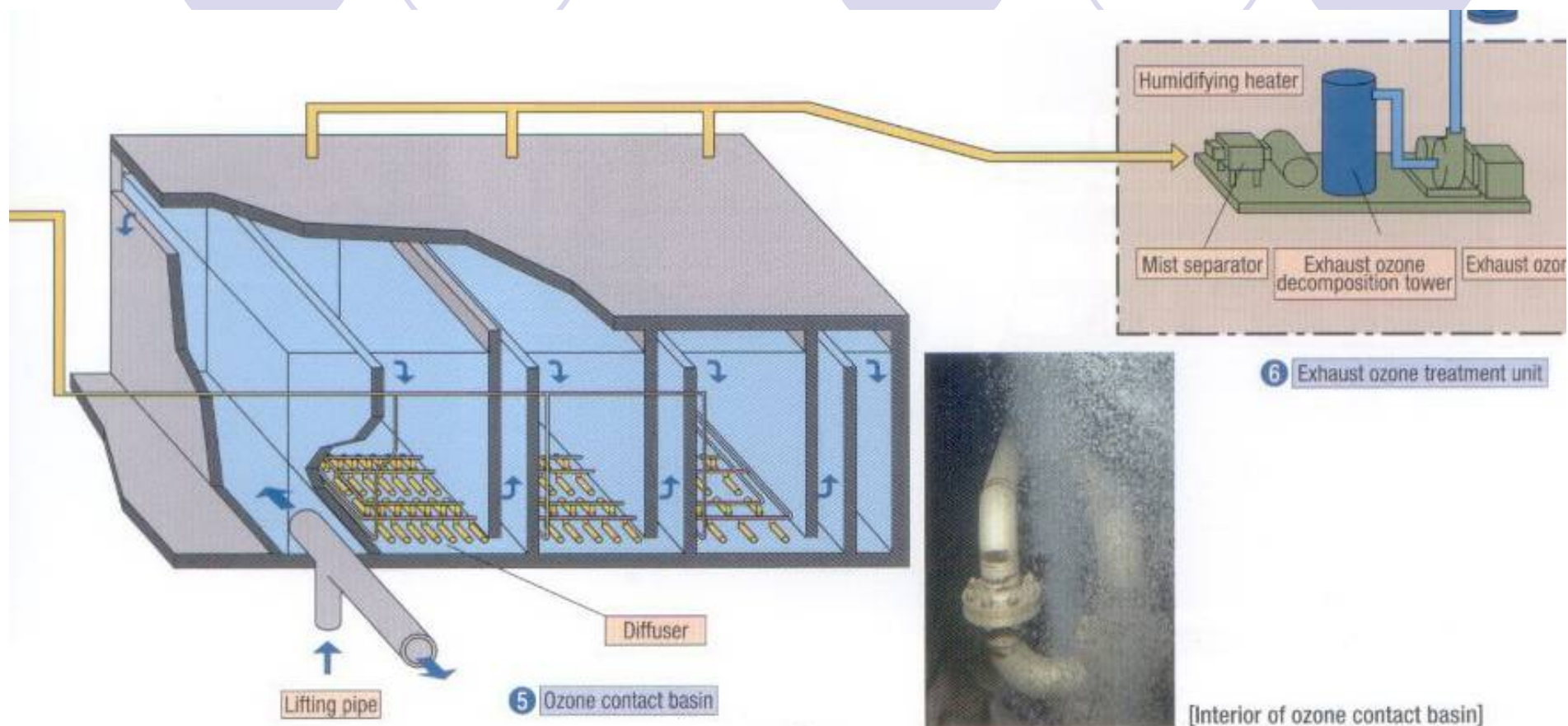
排臭ガス処理機は、活性汚泥法
曝気槽の底水及び浮遊物を除去
される際に発生した臭素をヤ
ン酸化性炭素に還元させ、無害
にして排水中の酸素に還元します。
処理機は、形状が円筒形であり、
底部に対して1層設置されており、
曝気槽から排出された汚泥によ
り構成されています。
処理機の構造は、円筒形で、外
径約1.5m、高さ約1.5mで、ス
テンレスにより製作されています。



酢酸ソーナ塩液は、酢酸性硫酸最良の濃水及び洗浄時に用いられる反応で得たソーナを中和反応性成分に調整させ、廃液にして排水の処理に供すること。塩液は、酢酸性硫酸最良の地に対して「高濃度」であり、最良地からFPO製のタンクにより運搬されています。塩液の構造は、円筒形で、外径約24m、高さ約10mで、スチール製により製作されています。

Ozonation

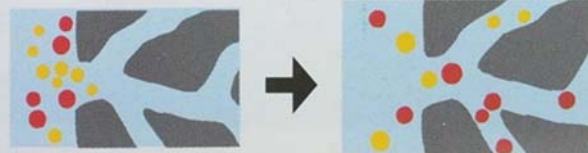




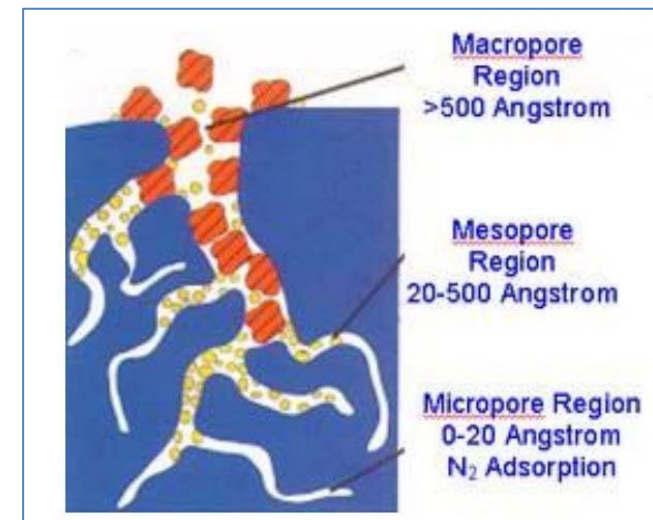
■ Structure of Granulated activated carbon particles



The countless pores create openings to the inside of a granulated activated carbon, and as a result these particles have a vast interior surface area of 1,000 sq.m. per gram.



Organic compounds are enveloped by pores in the activated carbon.



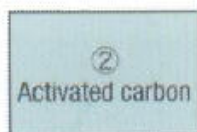
Granular Activated Carbon



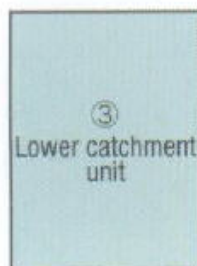
GAC Treatment Facility



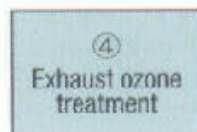
- Construction — Downflow, gravity, natural equilibrium system
- Space velocity — Approx. 6.0 (1/h)
- Linear velocity — Approx. 16.2 (m/h)
- Total basin area — Approx. 113.6m² x 32 basins
Approx. (W) 4.0m x (L) approx. 14.2m x 2
- GAC bed depth — 2.7 m



- Type — Coal-based GAC
- Granule diameter — Average granule diameter: Approx. 1.0mm
- Volume of activated carbon — Approx. 9,800m³

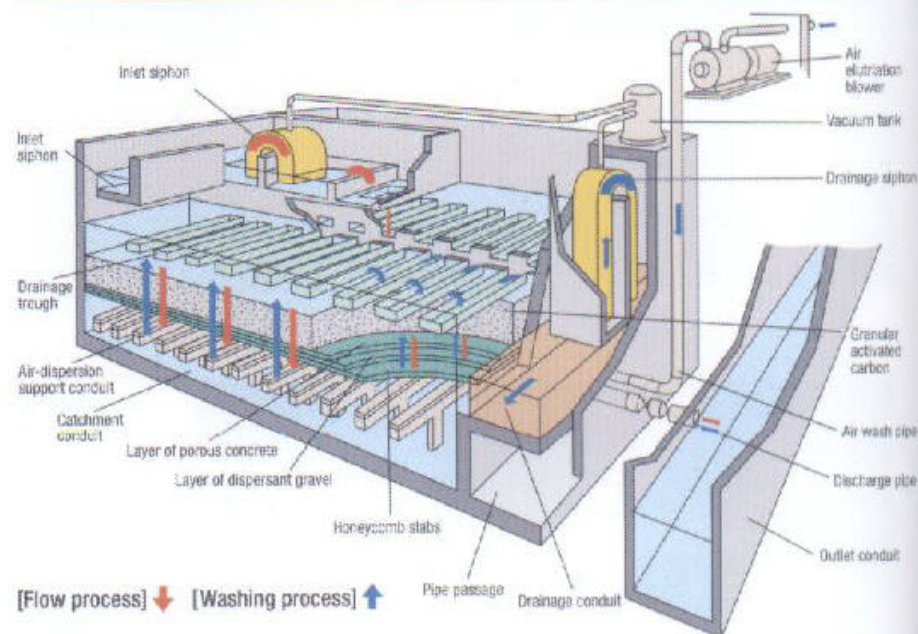


- System — Unit-type porous plate
- Washing method — Simultaneous air/water washing
Air intensity: 0.8m³/m²/min.
Backwashing with air/water: 0.2 m³/m²/min.
Water backwashing intensity: 0.4 m³/m²/min.
*0.56 for water backwashing in summer
- Washing water — Activated-carbon self-treated water



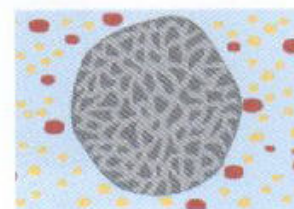
- Method — Activated-carbon catalytic cracking
- Treatment cylinders — 8 sets (1 set/4 basins), indoor type
- Goal — To reduce ozone concentration to 0.06ppm or less

Treatment process



[Flow process] ↓ [Washing process] ↑

Structure of Granulated activated carbon particles



The countless pores create openings to the inside of a granulated activated carbon, and as a result these particles have a vast interior surface area of 1,000 sq.m. per gram.



Organic compounds are enveloped by pores in the activated carbon.

Advanced Water Treatment

Disinfection
Murano WTP

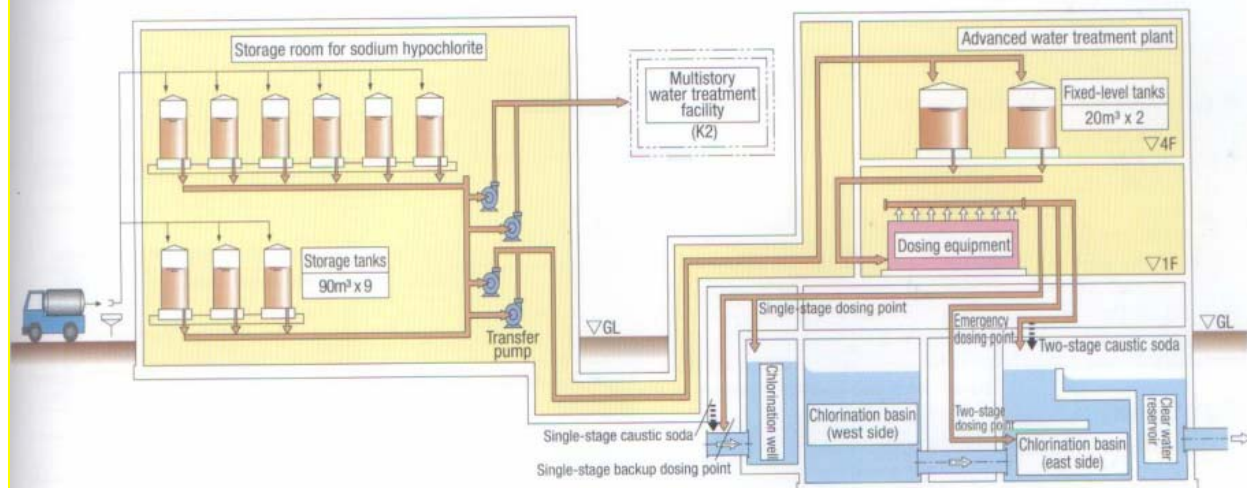
Sodium Hypochlorite Dosing Facility



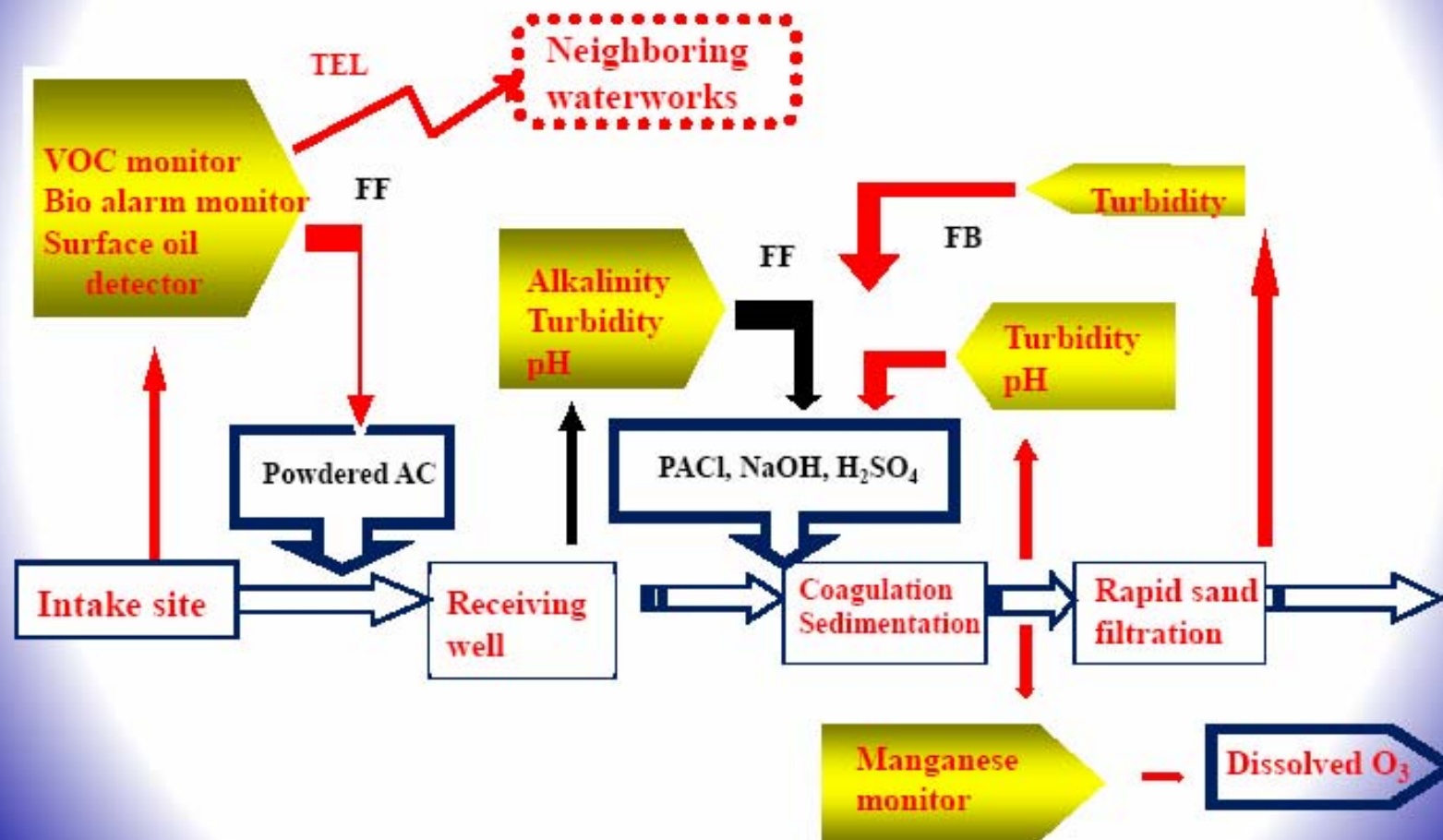
[Storage tanks]



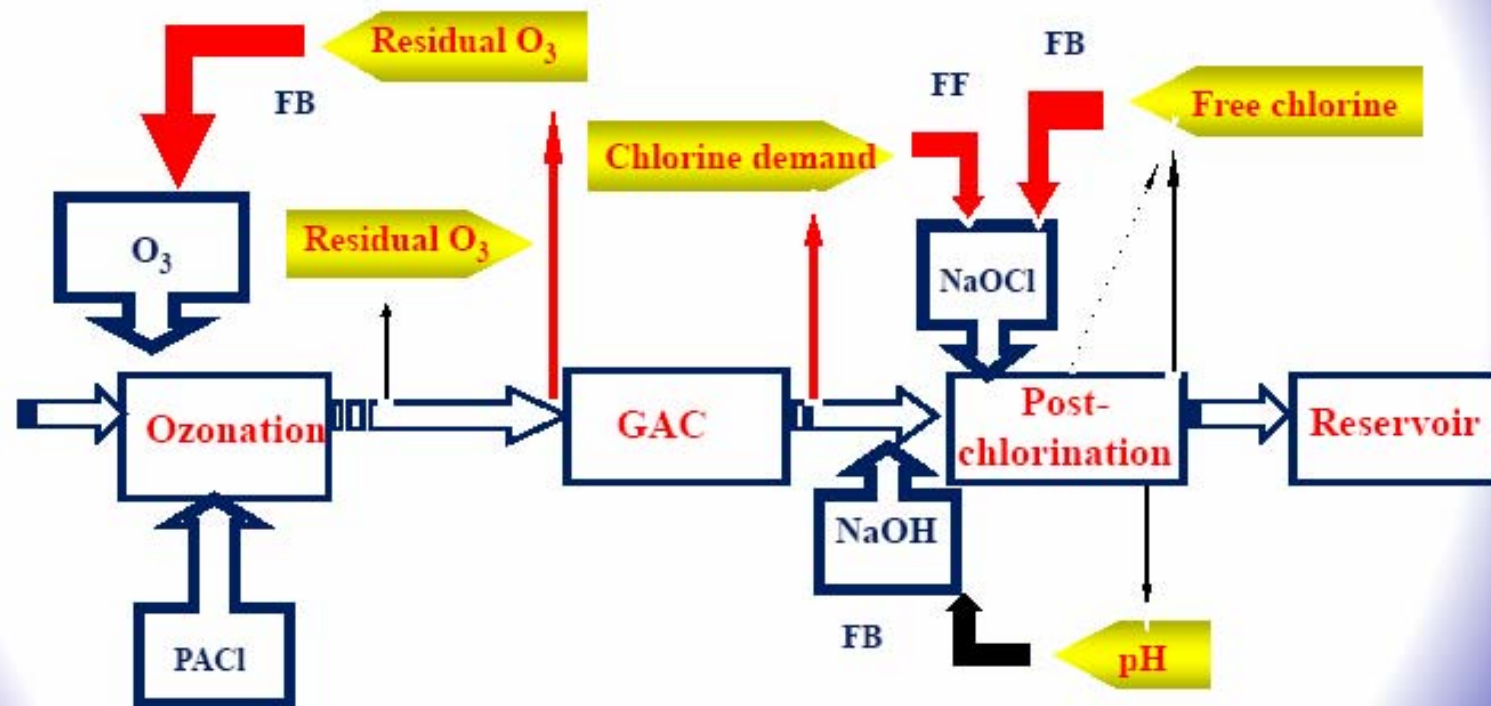
[Dosing equipment]



Water Treatment Process Controls of OWSA (1)

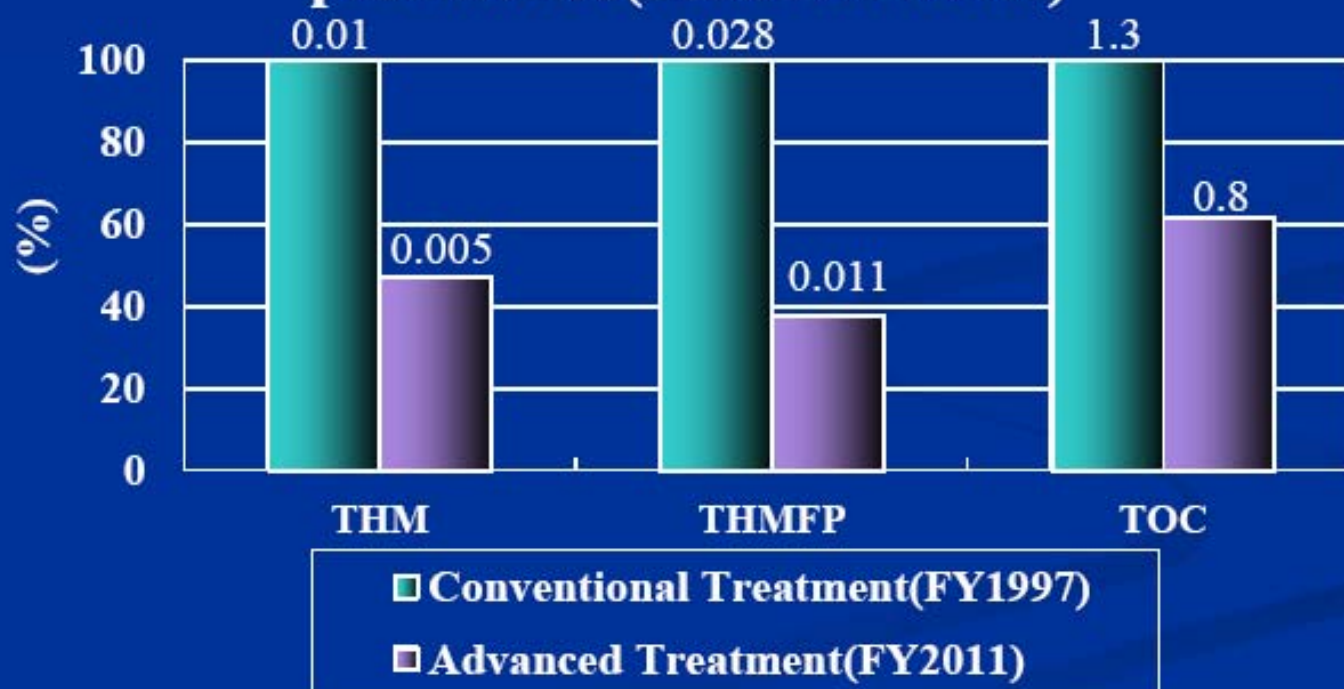


Water Treatment Process Controls of OWSA (2)

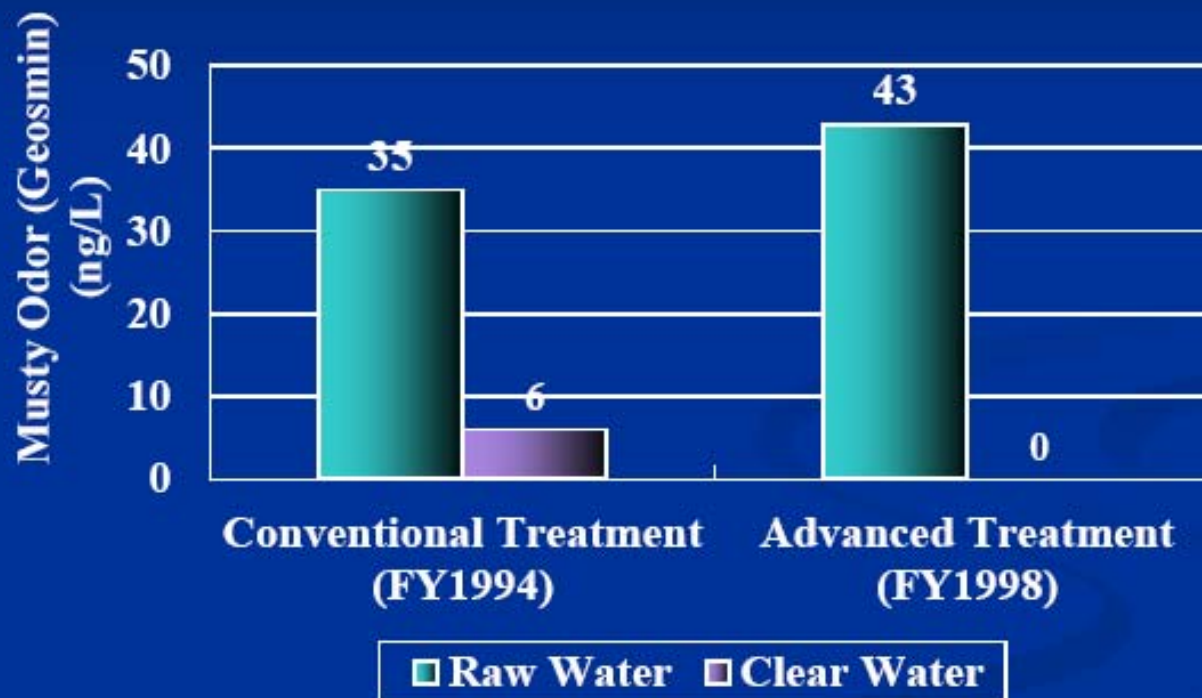


Effect of Installation (Removal of Organic Matters)

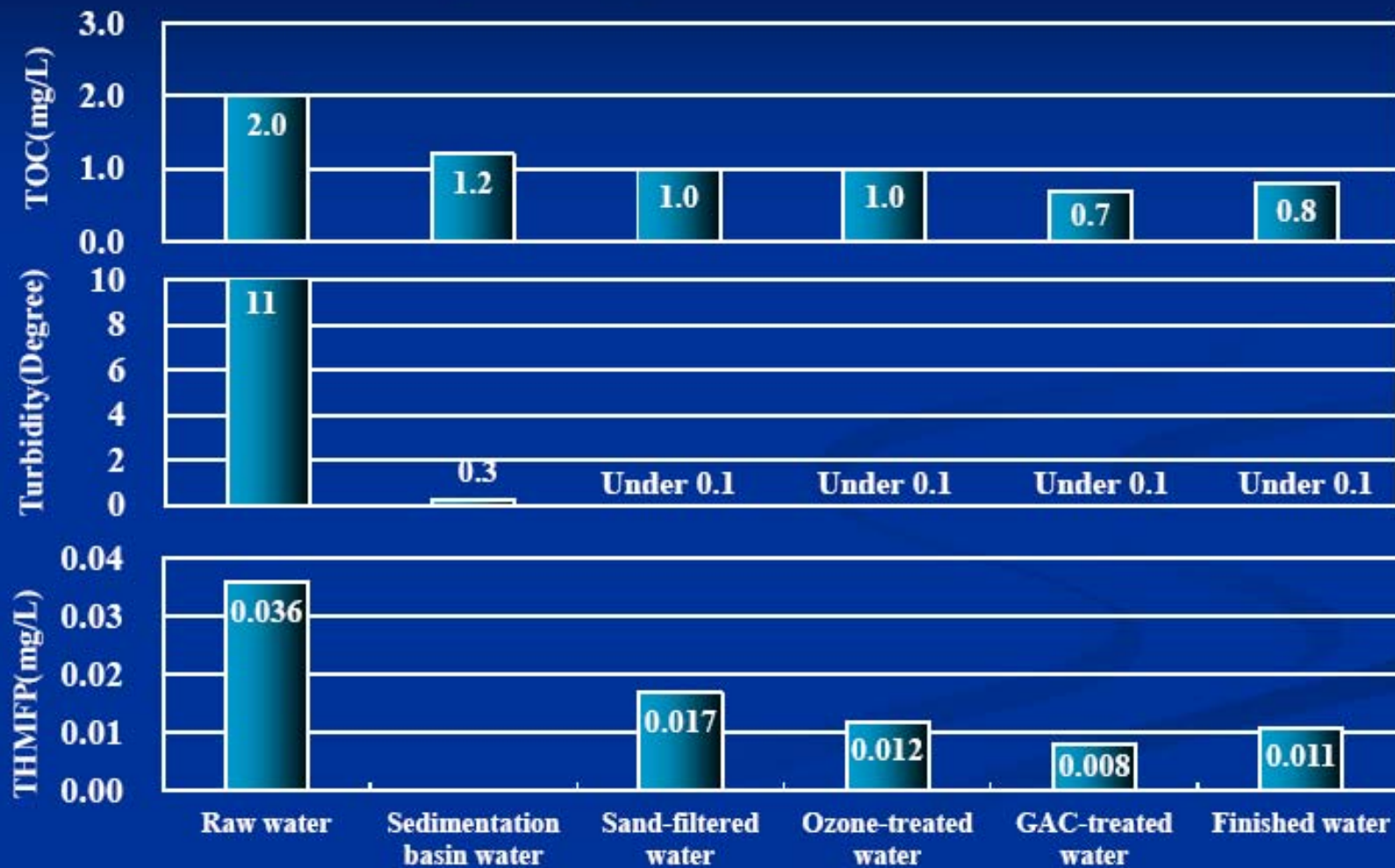
Comparison of the typical water quality
parameters(Finished water)



Effect of Installation (Removal of Organic Matters)



Water Quality at Each Process



Issues After Installation (By-products of Ozonation)

Bromate : Standard value=0.01mg/L

(Added to Japanese Drinking Water Quality Standard in 2004)

Minimizing bromate formation by optimizing ozone dosage

	Maximum	Minimum	Average
FY2003	0.0082	0.0033	0.0056
FY2004	0.0059	0.0013	0.0035
FY2005	0.0028	0.0006	0.0017

unit : mg/L

Issues After Installation (Appearance of Algae)

- Stop of pre-chlorination
 - Clogging of plate settler
 - Mud-ball at sand-filtration basin

Solution

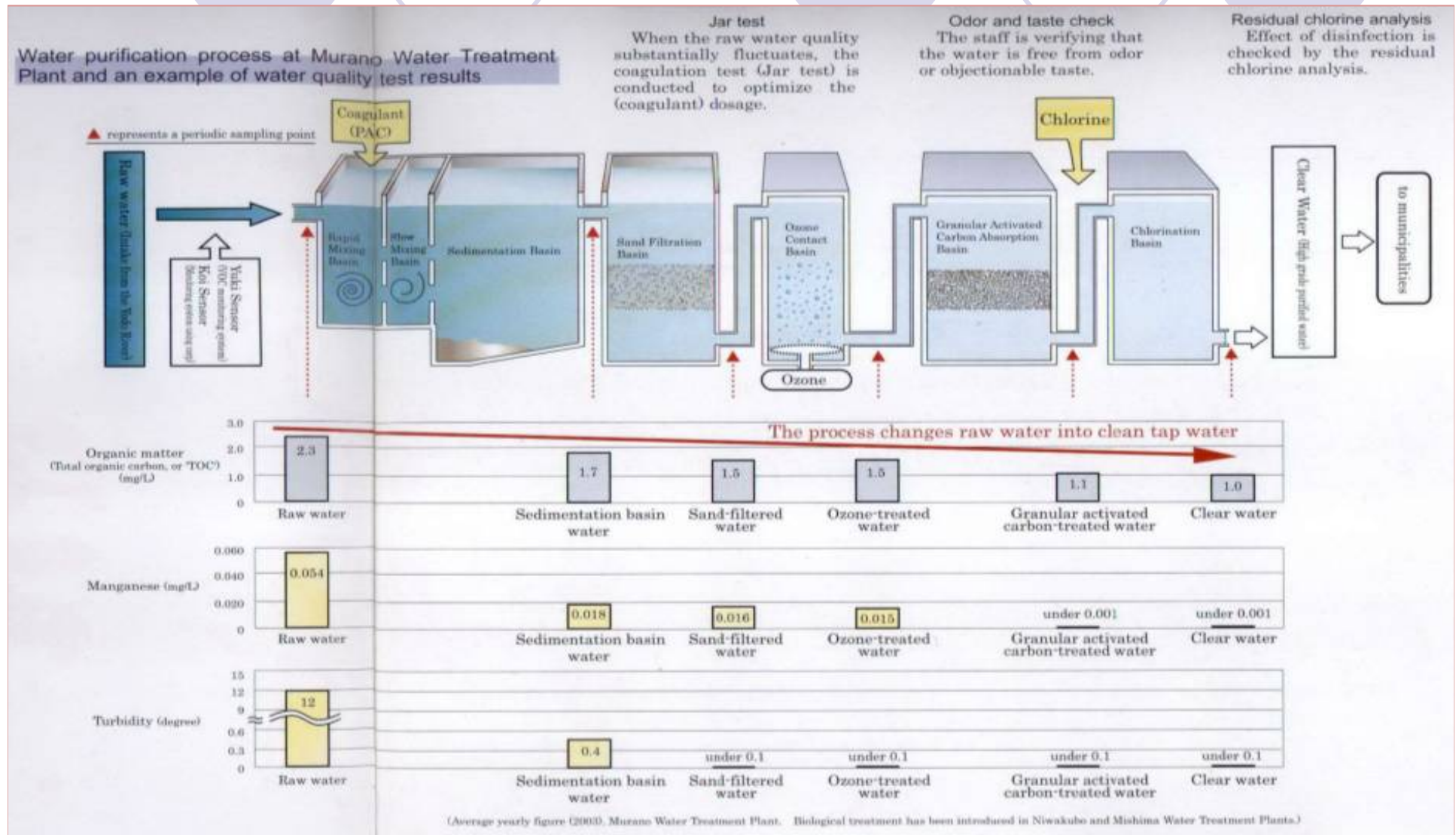
- Installation of the cover over sedimentation basin (plate settler)
- Installation of the cover over sand filtration basin (planned)

Effect on Water Quality of Advanced Water Treatment (Murano Plant, Osaka)

		Drinking W. Std.		Quality Before		Quality After	
		Std.	Guideline	Raw W.	Treated W.	Raw W.	Treated W.
Musty odor	2-MIB [ng/l]	—	≤10	50	40	12	ND
	Geosmin [ng/l]	—	≤10	362	173	37	ND
TON		—	≤ 3	24	6	27	2
Potassium permanganate consumption value	[mg/l]	≤10	≤ 3	6.9	1.9	6.8	1.0
THMFP	[mg/l]	—	—	0.043	0.032	0.042	0.010
Anionic surfactants	[mg/l]	≤ 0.2	—	0.03	0.02	0.03	ND

- http://www.jwrc-net.or.jp/aswin/projects-activities/rd_files/jp-sg_symposium/2012_07_01.pdf

Advanced water treatment plant

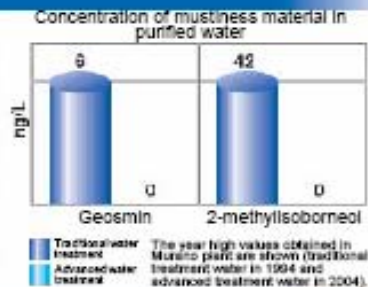


After Advanced WTP is introduced In Summary



1 No mustiness

Mustiness is caused by substances (Geosmin and 2-methylisoborneol) produced by planktons such as Anabaena. As shown at right, the advanced water purification eliminates mustiness completely.



2 Drastic reduction of trihalomethane (THM)

The values of total THM and total THM generative capacity are reduced dramatically by introduction of the advanced water purification.

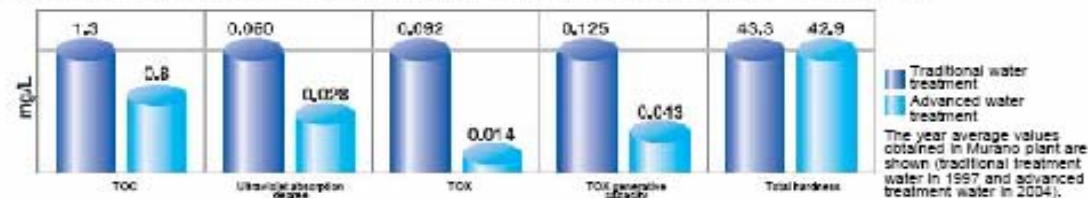
Traditional water treatment
Advanced water treatment

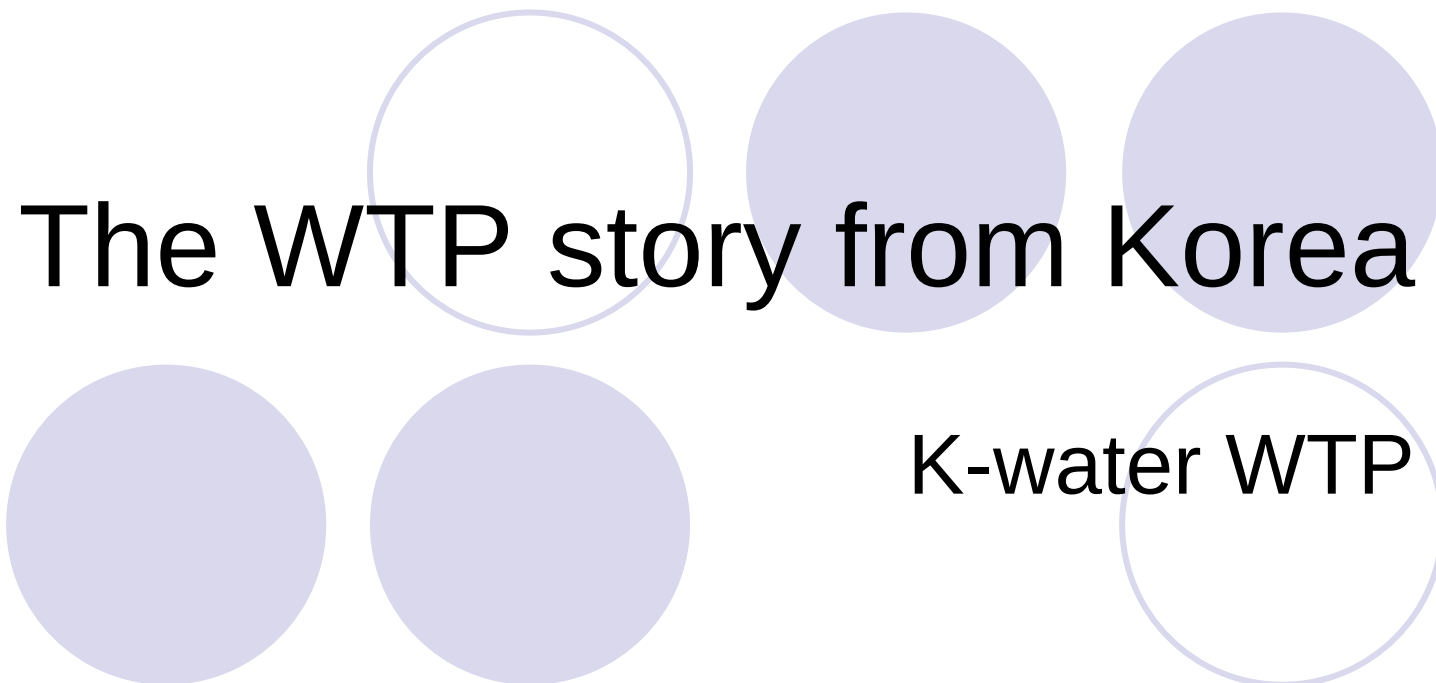
The year average values obtained in Murano plant are shown (traditional treatment water in 1997 and advanced treatment water in 2004).



3 Overall water quality improvement

As for the rest, values of TOC (organic matter), TOX (total organic halogen) and so on have reduced. Furthermore, trace organics such as pesticides are eliminated effectively and safety of the purified water has increased. On the other hand, there is almost no variation in hardness of mineral component which improves taste.



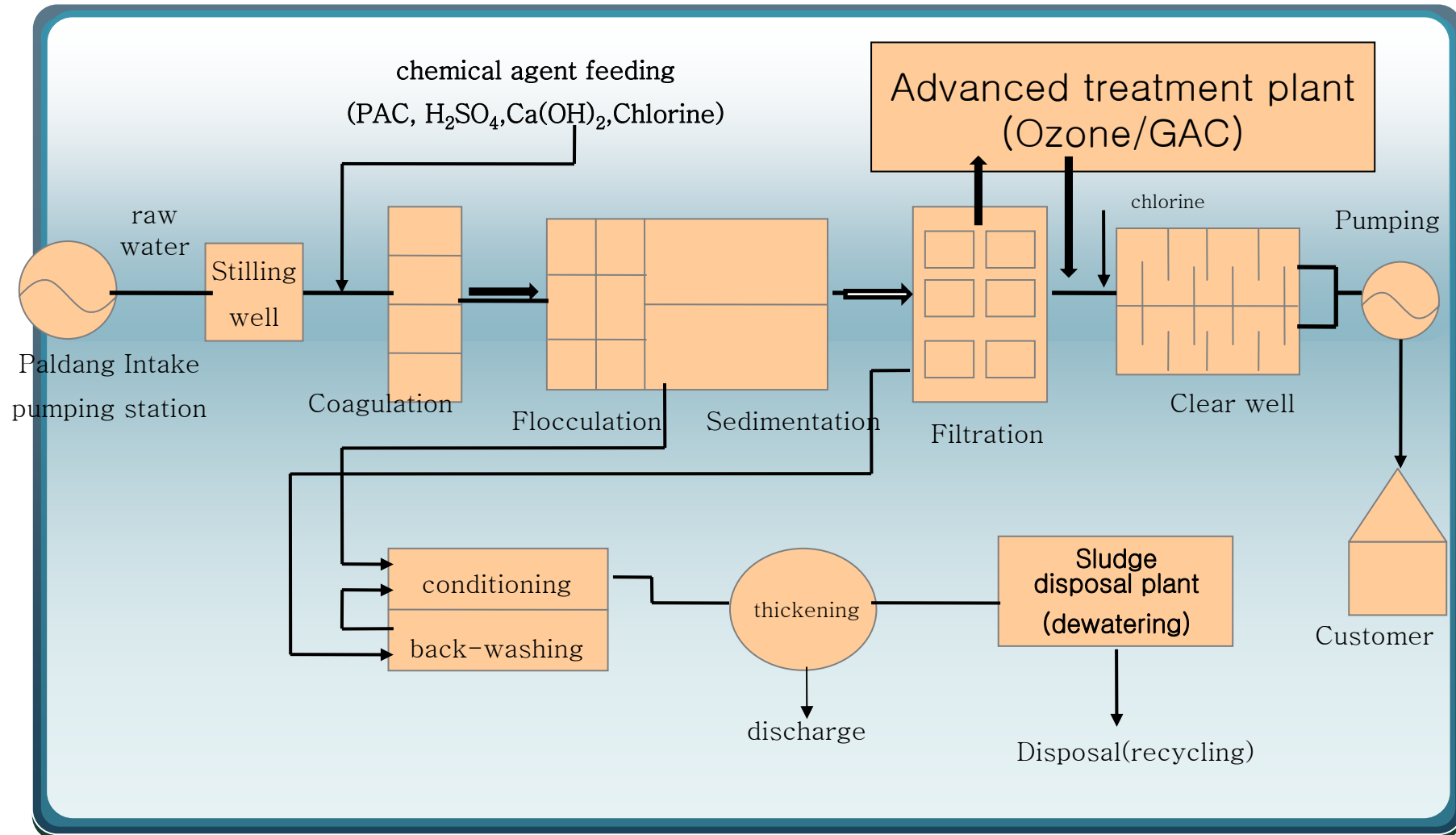


The WTP story from Korea

K-water WTP

Facilities

Water Treatment Process



The Others

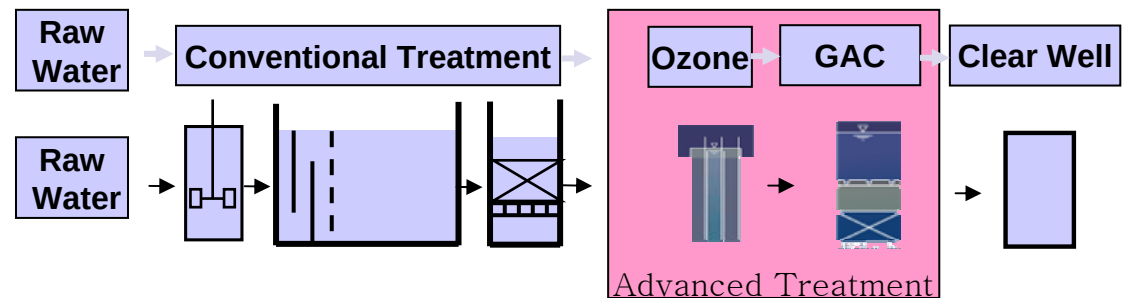


Advanced Water Treatment Project



◆ Purpose : Removal Taste & Odor

◆ Process : Ozone & GAC



Ozone generator

2

오존발생기 2 호기 오존발생기 (OZON GENERATOR)

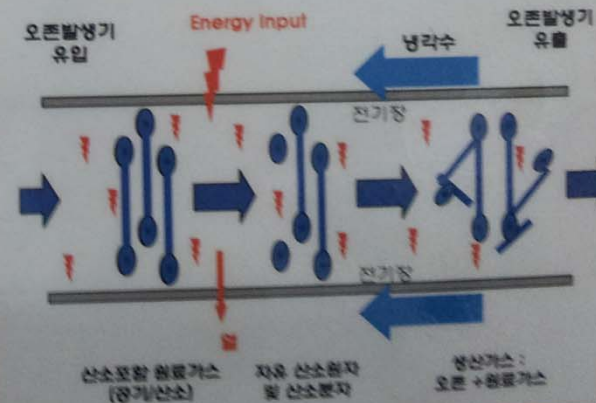


기기명 : 오존발생기
기기번호 : MA-103-2
규격 : 무성방전 중주파 수냉식
오존생산량 : 17.3kg/hr,
농도 : 12wt% (178g/Nm³)

용도 및 작동원리

용도 : 공급되는 공기(산소)를 전기화학적으
로 분해하여 오존생산

작동원리 : 방전관에 중주파 고전압을 인가하
여 전기장을 형성하고 전기장내 산소
를 통과시켜 코로나현상에 의하여 산
소분자를 파괴하여 파괴된산소 원자
가 산소분자와 결합하여 오존(O₃)이
생성된다



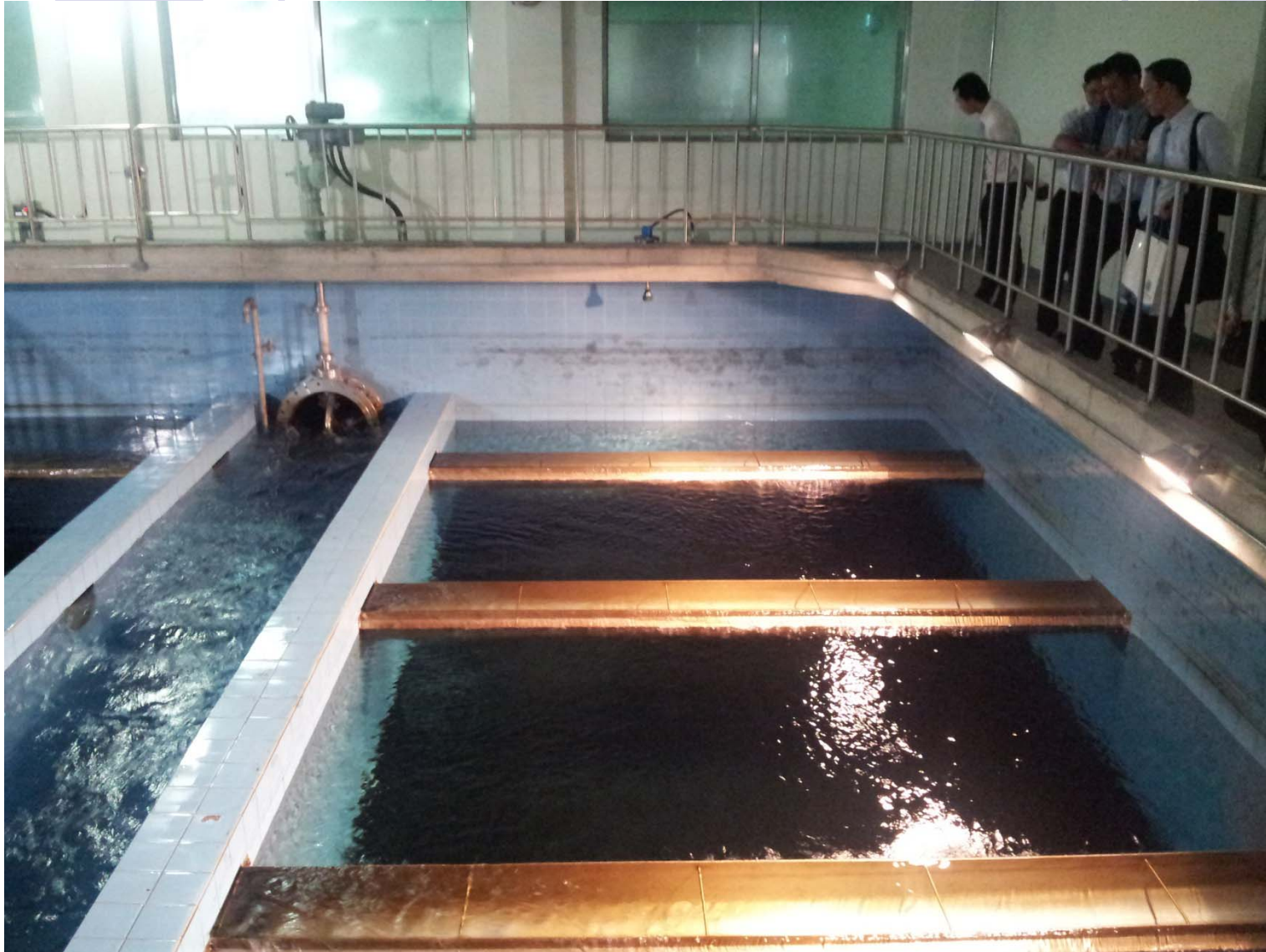
Ozone generator



Side-stream Ozone Injection



GAC



The Others

Ozone /GAC

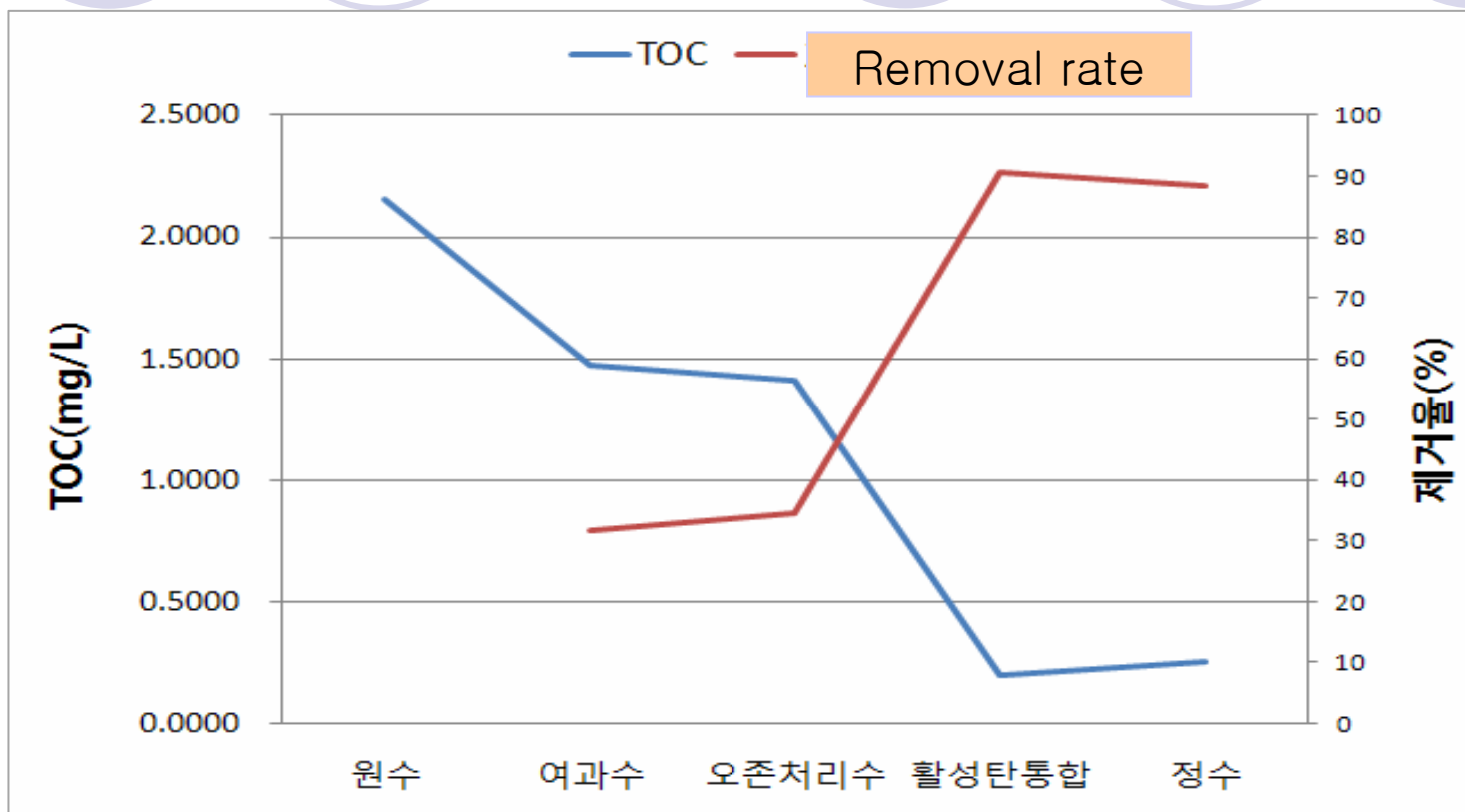
Oxygen



Side
Stream
injection

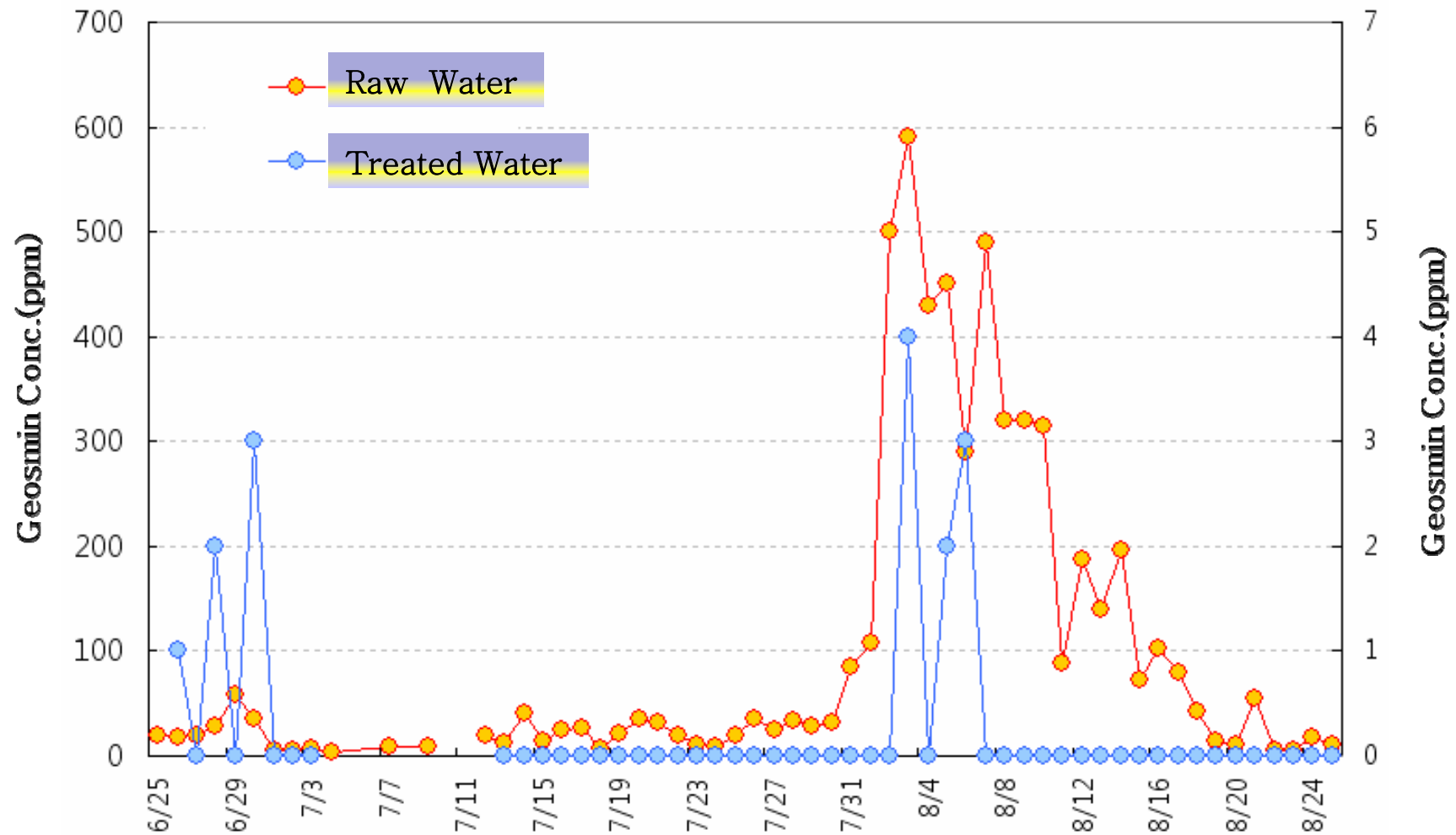


Removal of Organics

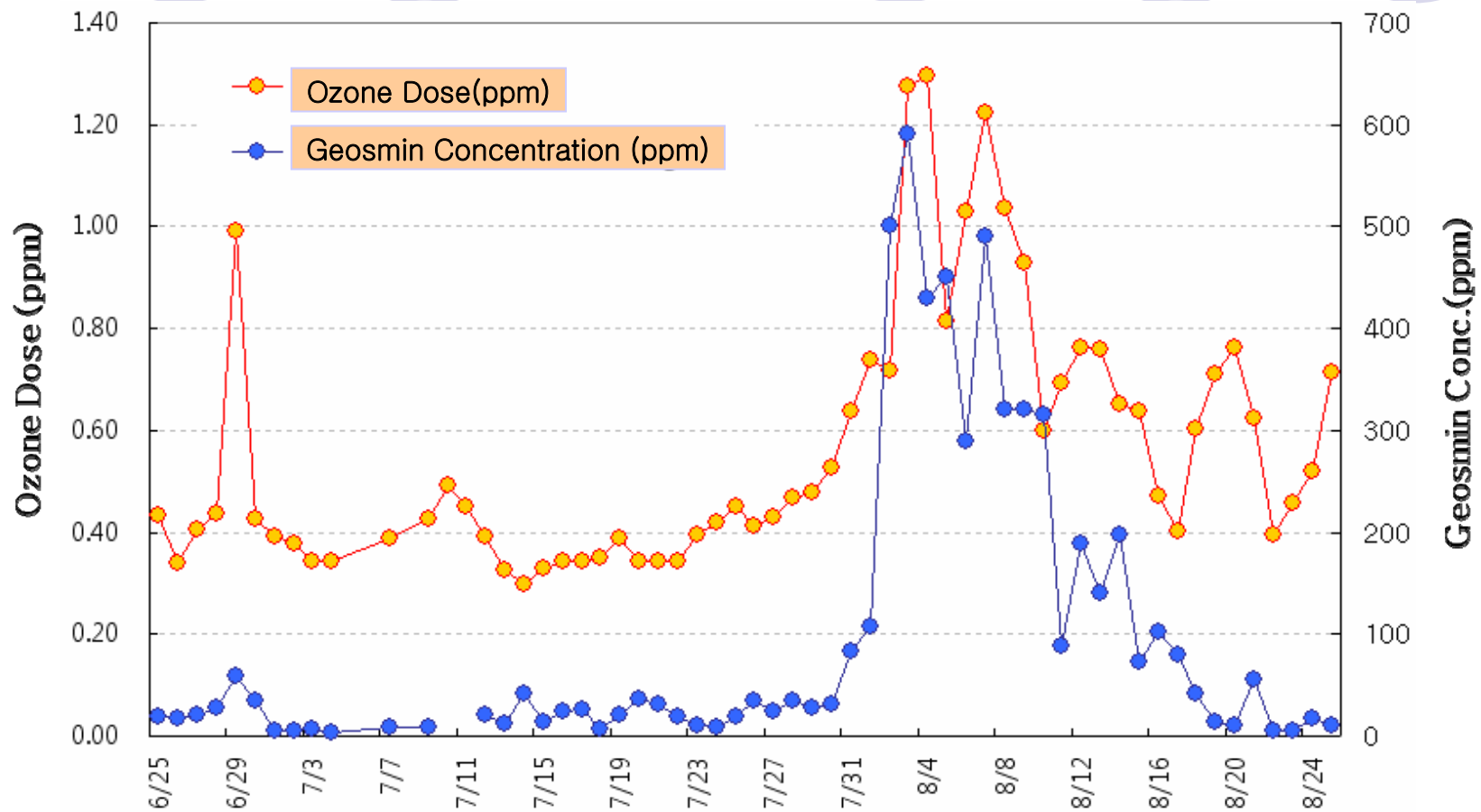


	Raw	filtered	Ozone	Ozone+GAC	Tap water
TOC (ppm)	2.15	1.47	1.41	0.20	0.25
Removal rate	-	31.5%	34.4%	90.6%	88.4%

Removal of Taste & Odors



Ozone Dose



	Average	Max.	Min
Ozone Dose(ppm)	0.56	1.3	0.3

A Case of **Water Supply Suspension** due to accidental spill near Tokyo

Occurred on 17th-20th in May, in Tone & Edo river basin

Accidental spill of hexamethylenetetramine (HMT) which was drained out from an industrial-waste disposal business into rivers.

Being combined with chlorine, HMT generated formaldehyde.

Drinking water quality standard of formaldehyde - 0.08 mg/liter.

Purification plants with advanced treatment were able to maintain the standard.

But plants without advanced treatment were not able to maintain the standard and had to suspend water intake and supply.

JWRC

Lining up for emergency supply



So...Before making a decision...

- Your Country
- Your People
- Your organization: Vision, Executive, Staffs, Strategy, etc.
- Your existing condition: Raw water, Water supply, water tariff rate...and.
- Your Financial !!!

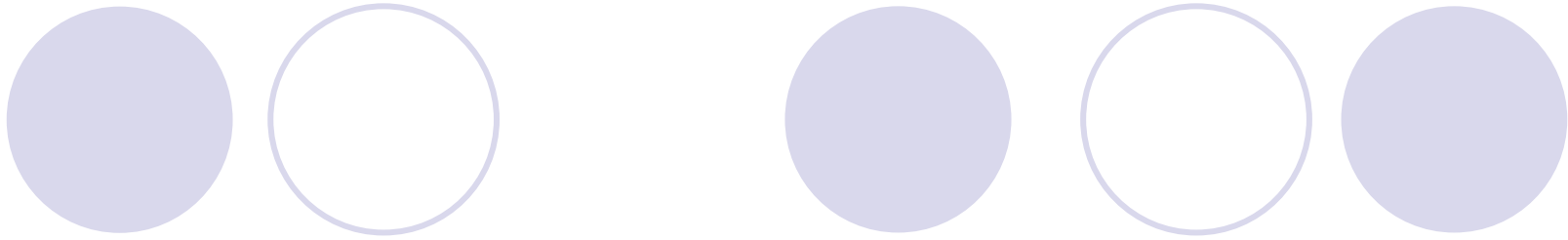


Reference

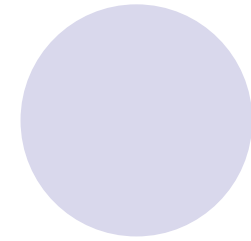
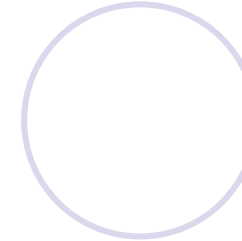
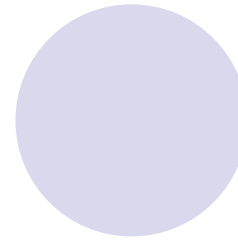
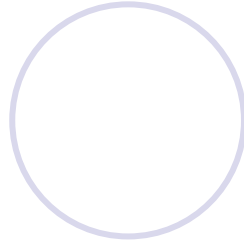
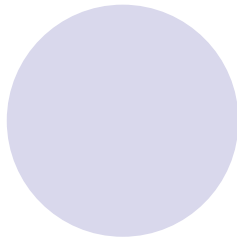
- Susumu Kawamura. Integrated Design and Operation of Water Treatment Facilities
- http://www.safewater.org/PDFS/resourcesknowthefacts/Conventional_Water_Filtration.pdf (latest accessed 01112013)
- http://water.epa.gov/learn/kids/drinkingwater/watertreatmentplant_index.cfm (latest accessed 01112013)
- EPA Guidance Manual: Alternative Disinfectants and Oxidants
- http://www.jwrc-net.or.jp/aswin/projects-activities/rd_files/jp-sg_symposium/2012_07_01.pdf (latest accessed 01112013)
- <http://www.water.ca.gov/education/images/watersupplyuse-l.jpg> (latest accessed 01112013)
- <http://www.neatorama.com/wp-content/uploads/2009/12/water-500x287.jpg> (latest accessed 01112013)
- <http://savethewater.org/wp-content/uploads/2012/06/Stock600-savethe-water-bottles-cost-to-the-envirement1.jpg> (latest accessed 01112013)
- <http://www.lenntech.com/water-quantity-faq.htm#ixzz2jNXiOLXe> (latest accessed 01112013)
- <http://ga.water.usgs.gov/edu/earthwherewater.html>(latest accessed 01112013)

THANK YOU





- 1 psig(pound/square inch [gauge]) = 0.0689475728 bar = 0.689 meter
- 1 scfm(standard cubic foot per minute) = 0.02831684659 cubic meter per minute



304 VS. 316 Stainless

The Differences Between Type 304 & Type 316 Stainless Steel

TYPE 304 STAINLESS STEEL

Type ³⁰⁴, with its chromium-nickel content and low carbon, is the most versatile and widely used of the austenitic stainless steels. Type ³⁰⁴ alloys are all modifications of the 18% chromium, 8% nickel austenitic alloy. Applications for this group of alloys are varied and all possess somewhat similar characteristics in resistance to oxidation, corrosion, and durability. All provide ease of fabrication and cleaning, prevention of product contamination and over a variety of finishes and appearances.

GENERAL PROPERTIES – TYPE 304

Type ³⁰⁴ stainless steels can meet a wide variety of physical requirements, making them excellent materials for applications including auto molding and trim, wheel covers, kitchen equipment, hose clamps, springs, truck bodies, exhaust manifolds, stainless atware, storage tanks, pressure vessels and piping.

TYPICAL ANALYSIS – TYPE 304

Represented by ASTM-A₂₄₀ AND ASME SA₂₄₀.

Elements by Percentage by Weight - Maximum Unless Range is Specified.

C = .08 / Mn = 2.00 / P = .045 / S = .030 / Si = 1.00 / Cr = 18.00 - 20.00 / Ni = 8.00-12.00 / N = .10

RESISTANCE TO CORROSION – TYPE 304

The 18% chromium, 8% nickel, provides good resistance to moderately acidic or caustic solutions. Type ³⁰⁴ may be considered to perform similarly in most non-severe applications. A notable exception is in the case of welding. Low carbon (³⁰⁴L) is the recommended alloy and provides increased resistance to intergranular corrosion.

MECHANICAL PROPERTIES OF TYPE 304 AT ROOM TEMPERATURE

Typical Mechanical Properties required for annealed material covered by ASTM A₂₄₀.

Yield Strength .2% offset = 30,000 / Ultimate Tensile Strength = 80,000 / Elongation = 50%. Hardness R = 90 max.

TYPE ³¹⁶ STAINLESS STEEL

Type ³¹⁶ is an austenitic chromium-nickel stainless and heat-resisting steel with superior corrosion resistance as compared to other chromium-nickel steels when exposed to many types of chemical corrodents such as sea water, brine solutions, and the like.

GENERAL PROPERTIES – TYPE ³¹⁶

Type ³¹⁶ alloy is a molybdenum bearing stainless steel. It has a greater resistance to chemical attack than the 304 family. Similarly, Type ³¹⁶ is durable, easy-to-fabricate, clean, weld and finish.

TYPICAL ANALYSIS – TYPE ³¹⁶

Represented by ASTM-A₂₄₀ and ASME SA₂₄₀.

C = .08 / Mn = 2.00 / P = .04 / S = .03 / Si = 1.00 / Cr = 16.00 - 18.00 / Ni = 10.00 - 14.00 / Mo = 2.00 - 3.00

RESISTANCE TO CORROSION – TYPE ³¹⁶

The addition of 2% molybdenum makes ³¹⁶ considerably more resistant to corrosion and oxidation than the 304 family of alloys.

MECHANICAL PROPERTIES OF TYPE ³¹⁶ AT ROOM TEMPERATURE

Typical Mechanical Properties required for annealed material covered by ASTM-A₂₄₀. Yield Strength .2% offset = 30,000 / Ultimate Tensile Strength = 80,000 / Elongation = 50%. Hardness R = 90 max.

Type ³¹⁶ is considerably more resistant to solutions of sulfuric acid, chlorides, bromides, iodides and fatty acids at high temperature. In the manufacture of certain pharmaceuticals, stainless steels containing molybdenum are required in order to avoid excessive metallic contamination.