# Water treatment technology using MU Static Spiral Perforated Wings (MU-SSPW)™

-A path from horizontal to vertical type of water treatment device-

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Technical partnership with MU USA Corporation

## 1. Introduction

### 1.1 Environment surrounding water resource

Today, with the worldwide development of the economy and its successive increase of population, the demand for water is accelerating. Under this circumstance, water pollution in some regions is getting critical due to the remarkable industrialization and urbanization propelled by the development of the economy. The pollution now becomes a social problem. Water is an essential foundation of our lives and it is inevitable for us to keep the water environment in good condition.

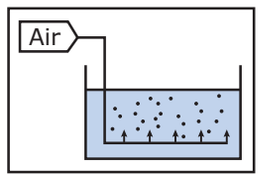
In the light of the condition, technologies of water treatment are getting more critical. Now a variety of devices for water treatment have been developed, and among them, our products are featured by saving-space, high efficiency, and maintenance-free, with the principles different from the conventional devices. This paper introduces our products for water treatment, then the principle of MU-SSPW (MU Static Spiral Performed Wings), the core technology of our devices, and finally proposes the vertical type of water treatment product, entirely different from the conventional horizontal type of water treatment. It would be appreciated if the paper causes a small ripple on the industry of water treatment.

### 1.2 Construct of the paper

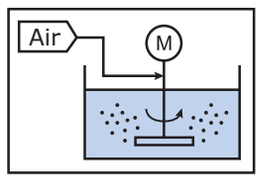
First, chapter 2 introduces various usages of our products in water treatment. Chapter 3 explains the principles of our products, inspired by the laws of nature, and the features, such as saving-space, high efficiency and maintenance-free, of our vertical devices. Chapter 4 describes our vertical products, MU Aqua Tower and MU Floating Tower, applied in a closed water area, such as pond and lake. And chapter 5 concludes the paper.

## 2. Main examples of exhaust gas and water treatment of our products

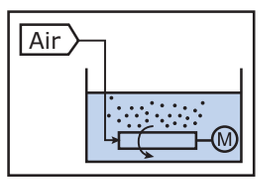
First, chapter 2 introduces various usages of our products in water treatment. Chapter 3 explains the principles of our products, inspired by the laws of nature, and the features, such as saving-space, high efficiency and maintenance-free, of our vertical devices. Chapter 4 describes our vertical products, MU Aqua Tower and MU Floating Tower, applied in a closed water area, such as pond and lake. And chapter 5 concludes the paper.



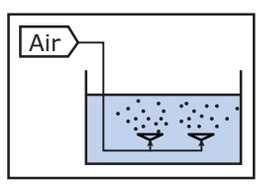

(1) Aeration by air nozzle
-Air nozzle just by holes on pipe or with spray nozzle



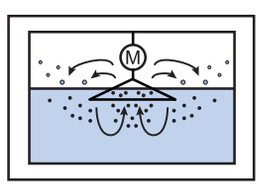

(2) Rotation type
-Agitate by feeding air into rorating turbine disk




-Blow air from rorating drum




(3) Filter module type
-Blow air from fine pores of filter




(4) Surface aeration type
-Contact water with air by sprinkling water using hung-up pump

Fig. 1 Conventional Aeration Method

### 2.1 Aeration in aeration tank

The first example is an improved treatment for exhaust water in aeration tank. Aeration in tank is performed by many methods as shown in Fig. 1. But these disadvantages are:

1. Frequent failure by the dirtiness and clogging of devices
2. A need of regular cleaning to avoid generating toxic gases, such as $H_2S$, $NH_3$ and $CH_4$, due to polluted sludge deposited on the base of a tank.
3. Low effectiveness of the utilization of oxygen
4. Lack of durability

(Improved Example)

A plant had two sets of aeration tanks with each volume of 4,300$m^3$, aerated by a surface type of aeration, but had been long suffered from the generation of odor and flying mist. The tanks had been cleaned up once every two years. However, since the plant quitted the surface aeration and started to use one of our products, MU Aerator (MA-125 type), the product has successfully reduced the odor drastically and stopped generating the flying mist and toxic gases. The device also made the tanks free of maintenance,

which reduces the cost of maintenance drastically and cut the cost of electric power by 24%.

## 2.2 Degassing treatment of wastewater

The next examples of MU-SSPW are some applications of effective degassing treatment in wastewater. We have provided more than 30 sets of MU Scrubber for 35 years since the foundation of our company. The product tends to be repeatedly ordered by the same customers. Now we explain four main examples of the application: removal of chlorine organic compound in wastewater, degassing of brine water, $CO_2$ removal in seawater, and $NH_3$ stripping removal in wastewater.

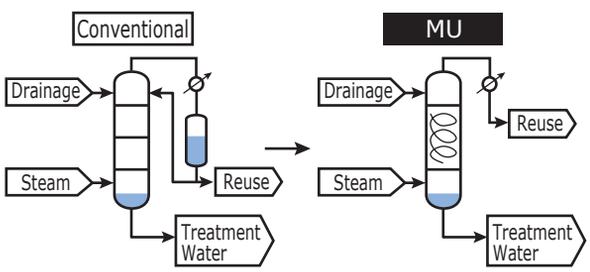
### 2.2.1 Removal of chlorine organic compound in wastewater

This example clearly shows a significant effect of one of the features of MU-SSPW, self-purification (Fig. 2). The objective of this unit is to remove chlorine organic compound contained in process wastewater by stripping with the use of sieve tray in a tower. This wastewater includes calcium-based substance and the substance is easy to extract, so the tower should have been stopped to clean up once every four months. Reboiler couldn't be used because of the easiness of clogging, so steam should be sent to the bottom of the tower directly. The exhaust water includes 300 wet ppm of chlorine organic compound and more than 90 % of the compound is reused in the process after stripping to the top of the tower to collect the substance. The tower has a diameter of 2.8 meters and eight layers of sieve tray, performing vacuum steam distillation. As it is getting dirty on the part of downcomer of sieve tray inside the tower, the rate of removal of chlorine organic compound is getting worse. To make up for the lowered efficiency of removal, the rate of reflux should be increased and the volume of wastewater be decreased. In spite of such measures, the operation is getting discontinued and should be stopped to open up the tower for cleaning. The series of actions had been repeated.

Changing sieve tray into MU-SSPW element can solve the first problem, the dirtiness and clogging inside the tower. The elements succeed in keeping the long-term operation without any interruption. Even ten years later from this improvement, the rate of removal of chlorine organic compound keeps more than 95% and the tower can be operated with a stable low differential pressure. The saving of energy and maintenance cost and the increase of reuse of chlorine organic compound result in a synergetic effect.

### 2.2.2 Degassing of brine water

This is an example of the application of MU-SSPW to a device for degassing $CO_2$ and $O_2$ in the brine, including 20% wet of NaCl, under the condition of vacuum (Fig. 3). Under the severe condition, MU-SSPW is highly acclaimed by the customer for no clogging and its long-term stable operation (Photo 1, 2). The changing material of the device from corrosion-resistant metal into FRP would achieve the




| | Conventional | MU |
|---|---|---|
| Diameter | 2.8m | 1.5m |
| Drainage Volume | 400-600t/h | 600t/h |
| Concentration of chlorine organic compound in treated water | 20-30wt ppm | ≦10wt ppm |
| Removal Rate | 90% | ≧ 95% |
| Volume of Steam | 12t/h | 4t/h |
| Total Differential Pressure | 700mm$H_2O$ | ≦ 150mm$H_2O$ |
| Time for Continuous Run | 4 months | ≧ 10yrs |

Fig. 2 Improved example of removal of chlorine organic compound


Photo 1 Comparison between conventional and MU degassing tower

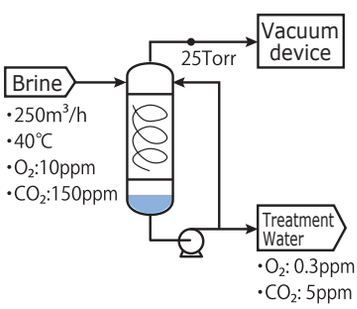



Fig. 3 Example of degassing of brine

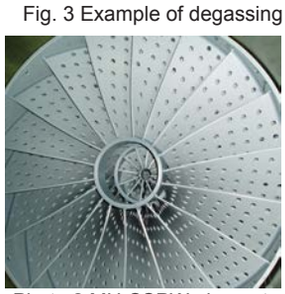


Photo 2 MU-SSPW element

long-lasting durability, which contributes to the reduction of initial investment.

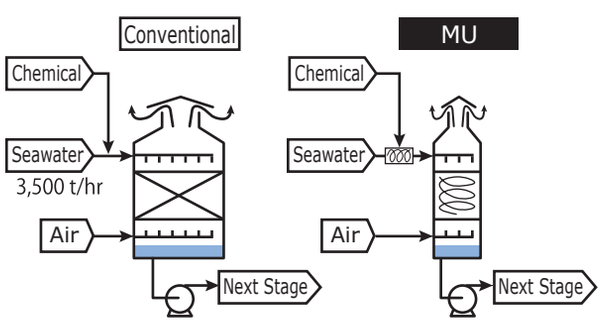
### 2.2.3 Removal of $CO_2$ in sea water

This example is an operational improvement of making air remove 100ppm of $CO_2$ dissolved in the exhaust seawater (Fig. 4). This operation needs big equipment and a large volume of air. However, the facility needed a large amount of maintenance cost because the packings were clogged by salt and the facility needed to be halted for cleaning. So, to tackle these problems, the following measures should be taken:

1. Change the packings into MU-SSPW element.
2. Add MU-MIXER into the feed line of sea water to ensure the pH adjustment.

Because salt makes the facility getting more dirt and clogged, the equipment needs to be bigger, which lowers the rate of gas-liquid contact. To keep the function of the equipment, the deterioration needs more air, which falls in a vicious circle.

By introducing MU-SSPW, the equipment can be kept clean, which breaks a negative circle. Downsizing results in the reduction of the volume of air absorption, leading to energy saving and the long-term stable operation.




| | Conventional | MU |
|---|---|---|
| Size of Tower | Φ6.8m×8m$^H$ | Φ2.8m×8m$^H$ |
| Packing | Irregular Packings 70m$^3$ | MU-SSPW Φ2.8m×2m |
| Material of Tower | CS + Resin Lining | FRP |
| Material of Internal | Resin | PP |
| Total Differential Pressure | 200mm$H_2O$ | ≦100mm$H_2O$ |
| Volume of Air | - | 60% Down |
| Volume of Power | - | 60% Down |
| Volume of Chemical | - | 50% Down |
| Cleaning | Once a year | No cleaning in more than 5 yrs |

Fig. 4 Improved example of removal of carbon dioxide in seawater

### 2.2.4 Removal of $NH_3$ in wastewater by stripping

MU-SSPW element is applied to a tower stripping NH3 contained in wastewater into air (Fig. 5). The whole volume of the tower is very compact since the flow of gas and liquid is countercurrent and the speed of gas inside the tower can be 2 to 4 m/s as design value. Air can be replaced with steam stripping, which achieves more than 90 % of the removal rate of $NH_3$ and less than 200 mm$H_2O$ of differential pressure inside the tower.

### 2.3 Removal of ethanol in the exhaust gas

This is a countercurrent absorption tower to change 7,000 volume ppm of ethanol in exhaust gas into less than 100 volume ppm of ethanol in it by absorbing ethanol in water. By using MU-SSPW, more than 98.5% of removal of ethanol can be achieved (Fig. 6). 3 m/s of gas speed will be within an area of flooding in the other conventional packing columns. Since the start of operation, years of safe operation of our products have continued. Fig 6 shows the specification of the tower.

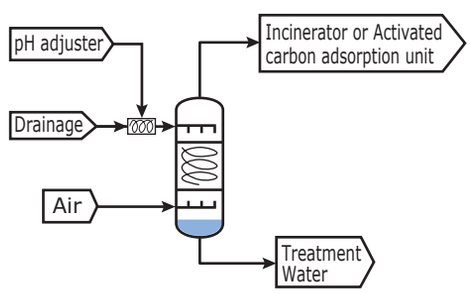
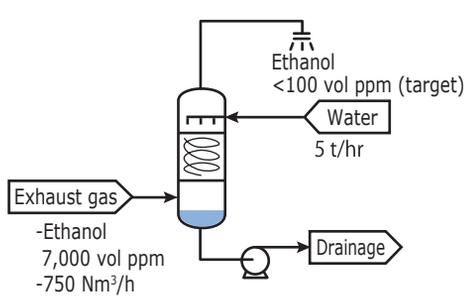



Fig. 5 Flow of removal of ammonia stripping




| | |
|---|---|
| Size of Tower | Φ350mm×3m$^H$ |
| Packing | Φ330mm×1.2m$^H$ (MU-SSPW Element) |
| Material of Tower | FRP |
| Material of Packing | PP |
| Total Differential Pressure | ≦100mm$H_2O$ |

Fig. 6 Flow of removal of ethanol in exhaust gas

### 2.4 Application to fish farm

Application of MU Aerator to exhaust water treatment is introduced in the above. Today, the aerator is beginning to be applied to fish and shrimp farm. This application shows that two types of aerators, MU Micro Bubble Aerator of high efficient rate of $O_2$ feeding by microbubbles and MU Aerator with strong churning power by spiral flow, can be used, according to the situation. In a farm pond, water wheel like Fig. 7 is often used for aeration. This disadvantage is the low dissolved rate of oxygen (3 to 4 ppm), and the sedimentation of feed and excrement at the bottom of a pond, which generates toxic gas by decay. The generation of gases pollutes the pond and it increases the consumption of chemicals for cleaning the pond. It is important to change the types of aerators, according to kinds of fish and shrimp to be cultivated. Just high rate of aeration or microbubble generation is not enough for fish farming. The optimal degree of aeration should be decided, together with customers, by different know-how from exhaust water treatment.

#### 2.4.1 Improvement of aeration in a pond for farming migratory fish

Installing MU Aerator (MA-125) at the bottom of a deep pond generates spiral flow (Fig. 8). This is applied for a pond in Australia, Peru and Vietnam. Thanks to the simplicity and friendliness for fish, the system is well accepted by customers.

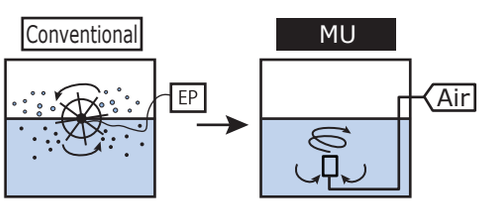


Fig. 7 Comparison of aeration in an aquaculture pond

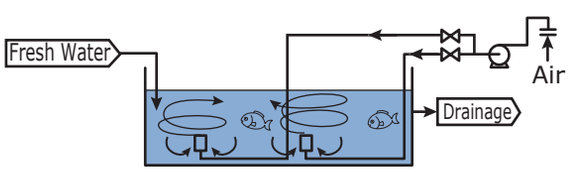


Fig. 8 Improved example of aeration in an aquaculture fish pond

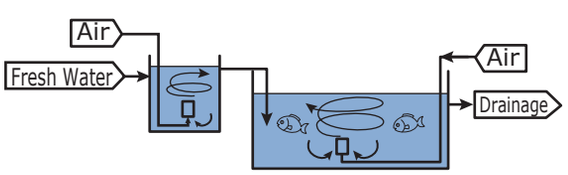


Fig. 9 Improved example of aeration in an aquaculture shrimp pond

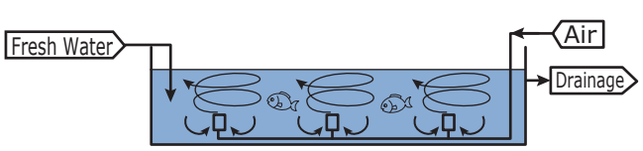


Fig. 10 Improved example of aeration in a live-box pond before shipping

#### 2.4.2 Improvement of aeration in a pond for farming shrimp

Aeration using a set of two tanks is utilized for the farming, considering the nature of shrimp (Fig. 9). In the upper tank, water with tons of microbubbles is generated. Water should flow into the lower reservoir for shrimp farming, where water is softly churned. This is applied for ponds in Indonesia, Thailand.

#### 2.4.3 Aeration of secondary tank for farming before shipping

Ten days before shipping, the fish are moved from farm pond to shallow tank ($10m^3$) for preparing for the shipping (Fig.10). Tank in Australia uses MA-25 for aeration.

### 2.5 Conclusion

As shown the above, our products achieve downsizing of the equipment, energy-saving, and maintenance-free, which considerably contribute to the reduction of initial and running cost. Further improvement of the products would lead to more effective product and be applied to a broader range of industries.

## 3. Principle of our products for wastewater treatment

In this chapter, we explain the nature of waterfalls, a source of the principle of core function, MU-SSPW, of our products. Then, we describe the relationship between the waterfalls and the product, followed by the law of MU-SSPW. Finally, we explain the features and applications of the product.

### 3.1 Physical function of waterfalls

Water in waterfalls can be shattered in a myriad of pieces by the interactions of the vertical difference of flow between the top and the bottom and the bumpy surface of a cliff. In waterfalls, water is divided by dropping and be hit on the surface of a rock. The flow of water is broken to pieces and further impacts make it the finer particles. In the end, the flow of water leads to mist, which keeps floating in air. In Guiana Highlands in South America, there

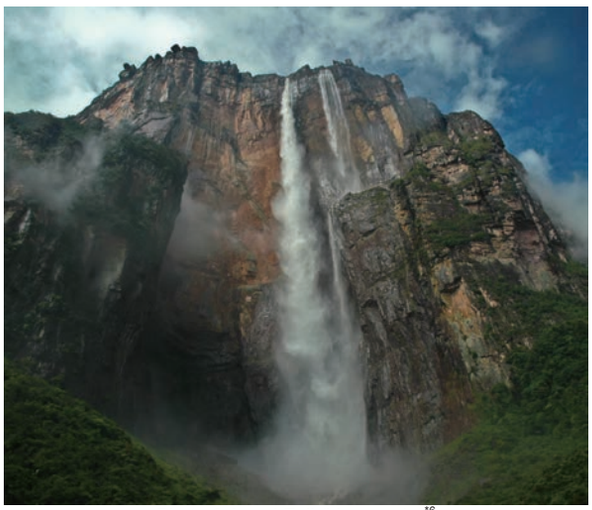


Photo 3 Angel Fall (Venezuela)[*6]

is Angel Falls, the world's highest uninterrupted waterfall, with a height of 979 meters (3,211feet) and a plunge of 807 meters (2,368 feet), as shown in Photo 3. In the waterfalls, when water is dropping, water hit on the surface of rock over and over again, which makes the dropping water finer particles. While the microparticle of water is falling, they get entangled in air and float there. In the course of falling, the flow of waterfalls is disappearing. In short, there is no waterfall basin. Height and irregularity on the surface changes flowing water into mist. The change of water into mist means that the contact area of liquid and gas phase is increasing.

### 3.2 Relationship between waterfalls and MU Mixing Element

MU Mixing Element embodies the law of nature artificially and efficiently by the refinement of water and its successive expansion of the contact area of liquid-gas phase like waterfalls (Fig. 11). MU Aqua Tower is a water treatment tower to be installed on the ground. Some layers consisted of MU Mixing Element are packed in the tower. When liquid falls through the elements, oxygen in air can be taken into liquid. With regards to the flow of water, firstly, water is pumped up to the top of the tower and then falls down through the MU Mixing Element, which makes water divided into pieces. The division leads to the expansion of the superficial area of water, which promotes the large volume of oxygen dissolved into water. The MU Mixing Element in the tower works as the bumpy surface of a rock in waterfalls. Only using the energy created by gravity, the tower reproduces the physical function of waterfalls.

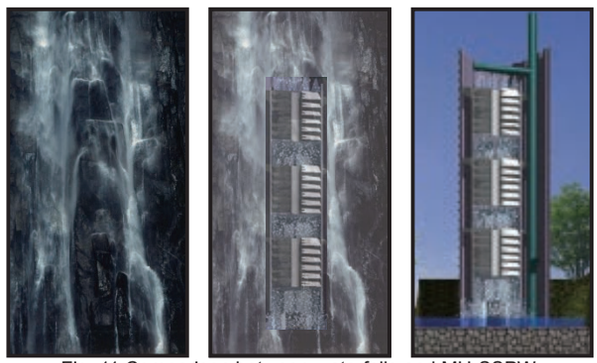


Fig. 11 Comparison between waterfalls and MU-SSPW

### 3.3 Outline of principle of MU Aqua Tower

In MU Aqua Tower, the collision energy of falling, brought by the potential energy of the liquid, can be converted into shearing forces in a myriad of directions, which divides liquid into pieces to increase the superficial area of liquid-gas phase. The Element is the heart of our products. So, what is MU Mixing Element all about? Inside MU Aqua Tower, multiple elements are placed, creating a cylindrical static mixer. Inside the element, multiple perforated wings are placed spirally and the center of the element in an axial direction is void. Because of the spiral placement of multiple perforated wings in an element, every time the liquid passes through the element, the liquid is continuously divided and mixed over time.

### 3.4 Principle of MU Mixing Element

So, why do spirally-twisted perforated wings suit for increasing the superficial area of liquid-gas phase? When the spiral wings have a lot of holes, a part of liquid flowing down along the wings pass through the holes on the wings. By passing through the holes, the different flow arises, together with the swirling current along the surface of the wings. These two different flows promote refinement of the liquid and another split is occurred by hitting each other. Now, when it comes to the form of spiral, the surface curves seamlessly and spirally from the top to the bottom. Now the liquid is flowing along the curving surface, moving spirally, which means that the moving distance from the top to the bottom is longer than the distance of free-falling, the one of vertical straight line. Since the distance of liquid moving on the surface is longer than the one of liquid falling straight down, the time of contacting liquid with gas is also longer than the time of free-falling. Moreover, as there are a lot of holes on the surface, some of the liquid on the surface is falling down from holes onto the lower wings. The moment

the liquid is coming on the verge of the hole, its movement and direction are decided by the inertial force along the blade, the viscosity, the strength and direction of force of wind. The very moment the liquid is about to fall down from the hole, the shearing force is brought by the gravity, which promotes the segmentation of the liquid. Inside the cylinder of MU Mixing Element, are several perforated wings set. The wings are set at any regular interval, and the more the area of the surface of wings per volume of the cylinder is, the more often the liquid flowing on the surface of the wings falls down onto the surface of the downer wings through the holes.

The more the area of wings per volume is, the more often liquid passes through the holes on the surface of wings, which means that liquid should be split into pieces more often. The density of area of wings is determined by two index. The one is the number of wings contained in an element. The other is the gentleness of curing of the wings. The more the number of wings is, the more the density of wings per volume is. Likewise, the more gentle the curving of wings is, the bigger the area of the wings is and the more the density of wings per volume is. The value obtained by dividing the area of wings with the volume of the element is defined as the efficiency of gas-liquid phase contact ($m^2/m^3$). The value is the key factor for scaling up the element.

These multiple wings are set inside MU Mixing Element as mentioned above. With regards to the way the wings are fixed, the inner periphery of the wings is welded onto the rings placed at the center of the circle of the elements. The outer periphery of the wings is also welded on the inner surface of the cylinder covering the whole wings. Since the rings are placed at the center of the element, the void is generated at the center in an axial direction. In the axial hole, there are no obstacle to block the axial flow of fluid. That means that the liquid passing through the hole free-falls and reaches at the bottom of the element. The axial free-fall flow is in a different direction from the spiral flow along the wings. Along the boundary phase between the axial flow through the void and spiral flow along the wings, the forces with different direction also work, which generates the shearing force on the boundary. The shearing forces also urge the liquid to be divided into pieces.

Now, let me wrap up the features of spiral perforated wings consisting of MU Mixing Element. First, the spirally perforated wings add the liquid flowing the wings

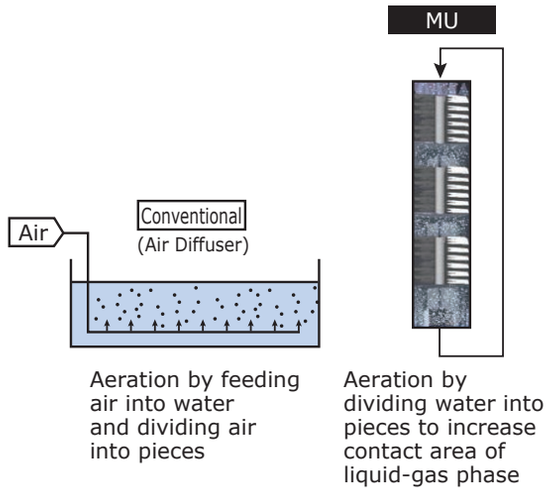



Fig. 12 Comparison between horizontal aeration device (diffuser) and vertical aeration device (MU Aqua Tower)

with some different kinds of shearing force in a various direction. The shearing force is generated when liquid passes through the holes on the surface of the wings and the liquid hit another flow of liquid falling down from the upper hole of the wings, and the axial flow in the center contacts the spiral flow along the perforated wings. These shearing forces with different directions enlarge the contact area of gas-liquid phase. Plus, the curving of the wings makes the flowing distance longer and the contact area bigger, which promote further refinement of the liquid. MU Mixing Element is an high efficient aeration device backed by the laws of nature, which are geometrically condensed and controlled by perforated spiral form and the difference between axial and spiral flows.

### 3.5 Features of MU Aqua Tower

#### 3.5.1 High efficiency and Saving space

Now let me explain the feature of MU Aqua Tower, which contains MU Mixing Element. The main feature of MU Aqua Tower is the enhanced aeration power brought by the expanded area of liquid-gas phase. The increased area results from the vertically piled up MU Mixing Element (Fig. 12). A conventional aerator is usually installed in water, but MU Aqua Tower is installed on the ground, not in water. The liquid-gas phase is increased not by sending air into water, but by dividing the target liquid into pieces. This is to say that the oxygen is taken into liquid by dividing water into pieces like waterfalls and wrapping the liquid with the surrounding air, not by infusing air into water. Using this way, aside from taking gas into liquid, when highly volatile substances, such as ammonia, dissolve

Photo 4 Details of waterfalls

into liquid, the substance can be efficiently got rid of from the liquid. And, by piling up the elements vertically and putting them inside the tower, a large volume of aeration can be performed only with a small space. Conventional aeration system needs a somewhat large space according to the volume of water. But MU Aqua Tower achieves high efficiency and saving space of the aeration system by making liquid impalpable.

#### 3.5.2 No maintenance by self-purification

Another feature of MU Aqua Tower is self-purification. By washing away dirtiness on the surface like waterfalls, the device doesn't need any maintenance. By the way, when looking into waterfalls carefully, the surface of rocks near the waterfalls is totally different up to how water hits the surface. The areas where the waterfalls always hit and a sheet of spray is created have naked rock surface with no mosses grown. The other areas, where the waterfalls don't hit and mist and moisture are created by the damp of waterfalls, are covered with mosses (Photo 4). When water falling down from the upper hit on the surface of a rock, the power with the rocky surface divides the water. On the other side, the falling water is hit on the surface and the water pressurizes the surface, which gets rid of any attachment on it. Water, together with the potential energy, is not only hit into pieces, but also clean the surface, up to the condition of the volume of flow of water, the shape of the surface of a rock, and the angle of water hit onto the rock surface. The fracture of water makes the surface of rock clean. This is true of MU Aqua Tower. When the liquid flows down on the surface of perforated wings of MU Mixing Element and it moves on the verge of a hole on it, the direction of flow of liquid dramatically changes and the liquid falls down through the hole. When it hit on the edge of a hole, the flow of water is torn by the gravity to divide the water into pieces. Up to the flow of water, velocity, and how the water hit on the edge of a hole, it is decided how water is divided into pieces. In the process of the segmentation of water, the end of a hole is pressured by the force of the segmentation of water, and the force makes the surface of wings clean. Some water falling down through the holes hit on the lower wings and clean the surface. In this way, by dividing water, the perforated spiral wings get clean. For this product, to divide water into pieces is to purify the wings themselves.

### 3.6 Application of MU Aqua Tower

In this way, features of MU Aqua Tower are a highly efficient and space-saving device due to the vertical type of aeration, and free-of-maintenance. This tower is basically installed on the ground, but this application, due to its high efficiency and saving space, is wider than any conventional aerators. For example, this tower can be installed on the surface of the closed water, such as a pond and lake, and be floating on it by making a structure and putting on it. MU Aqua Tower is originally a device to increase a contact area of the liquid-gas phase to dissolve oxygen with water, but it can strip volatile compound, like ammonia, contained in water into air (Ammonia Stripping). In the next chapter, we will explain how MU Aqua Tower as vertical aerator applies.

## 4. Water purification device using MU Mixing Element

### 4.1 Type and Mechanism

In this chapter, we introduce a list of water purification device with MU Mixing Element. Fig. 13 shows an example of the use of these devices, including MU Aqua Tower, MU Green Reactor and MU Floating Tower.

MU Aqua Tower is a tower type aerator with multiple layers of MU Mixing Element, free-falling water pumped

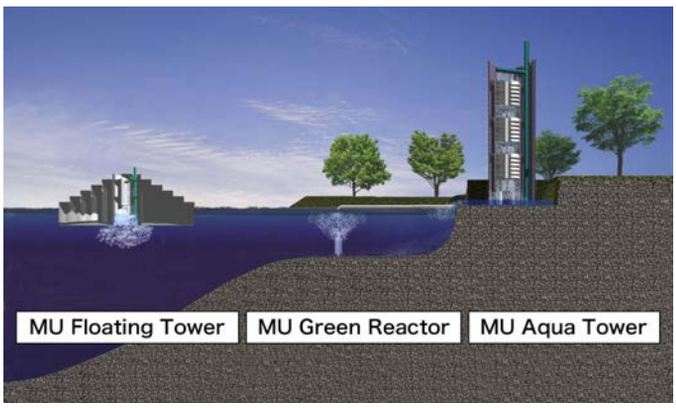


Fig. 13 Types of water purification device using MU-SSPW

up from lake or pond by a circulation pump to create artificial waterfalls and purify water effectively. The device is to dissolve oxygen into water by free-falling and crashing water with MU Mixing Element to divide water into pieces. The neighborhood of area where water should be purified, such as the shore of lake/pond, is often selected as a location of its installation.

MU Green Reactor is a water purification device used in the bottom of lake/pond. Root blower and compressor send fresh pressurized air into the bottom of the device to generate microbubble for adding oxygen into water. Air sent to the bottom of the device will be going up to the surface of water by buoyant force. By passing through some layers of Mixing Element, the air is divided into pieces, which generates microbubbles to help oxygen in the bubble dissolve into water.

MU Floating Tower is the smaller one than MU Aqua Tower and MU Green Reactor to float it on the water surface. MU Floating Tower has two types: a type with compacted MU Aqua Tower and the other type with MU Green Reactor in the underwater casing. Both can be floating like a ship and easy to remove and available for water purification of a wide area. The structure and type of MU Floating Tower are described as follows.

Fig. 14 shows the comparison of three types of aeration. All of the devices make the most use of laws of nature, like free-falling and the buoyant force of air in water, which can save energy as possible as it can. In the middle of worldwide serious energy shortage, the series is the futuristic water purification devices. Furthermore, all devices are designed to be compact, saving-space, saving-energy, and free-of-maintenance, which has little influence with ecological system.

## 4.2 Usage Area of MU Floating Tower

It seems that the biggest issue of water environment in the 21st century is the improvement of water in the closed water like lake and pond where the water is not likely to be

| Name | MU Green Reactor  | MU Aqua Tower  | MU Floating Tower  |
|---|---|---|---|
| Principle | High efficiency diffusion column with oscillation device and multiple spiral perforated wings | Stripping tower to supply circulation liquid from the top of the tower installed with MU Mixing Element, take in air using potential energy, mix and contact liquid and gas. | Stripping tower equipped with MU Aqua Tower or MU Green Reactor, floating on the surface. Off-grid power generation by solar/wind power. |
| Description | Mixing and churning liquid strongly, absorbed by air lift and compressed air, in Mixing Element to generate gas-liquid mixed flow in a smog condition. Underwater installation type. | New type diffusion type using the potential energy of liquid. Imagine dam's tailwater or waterfalls. Installed on ground. | Four types: Aqua tower type, Casing type, Air lift type and Green reactor type. All floating type. |
| Type | MGR-300 to MGR-1800 | MAQ-500 to MAQ-1800 | |
| Bubble | Microfine | Fine | Microfine / Fine |
| Oxygen transfer rate | 8 - 24 | 2 - 5 | 2 - 6 |
| $O_2$ transfer power rate kg・$O_2$/kWh | 2.3 - 3.6 | —— | —— |
| Advantage | -Robust over occlusion<br>-Strong power of churning and shearing<br>-Easy installation<br>-Micro bubble generation<br>-No need of compressed pump for liquid | -Robust over occlusion<br>-A large volume of circulation liquid<br>-Easy installation<br>-No need of blower for compressing air<br>-Micro bubble generation | -Robust over occlusion<br>-A large volume of circulation liquid<br>-Available for removing it underwater<br>-Available for purifying a deep part of water |
| Disadvantage | None | None | None |
| Remarks | -2 to 100 $m^3$/min of volume of supply air<br>-3.2 × $10^3$ kg/$m^2$h of gas mass velocity<br>-SS, SUS, Ti, Hastelloy, PP, PVC of Material<br>-Available for gas absorption and gas stripping | -4.0 × $10^2$ kg/$m^2$h of liquid mass velocity<br>-50 to 1,000 $m^3$/h of volume of circulation liquid<br>-SS, SUS, PP, PVC, FRP of material<br>-Best for collaboration of monumental design and water purification | See MU Green Reactor and MU Aqua Tower |

Fig. 14 Performance comparison of water purification device

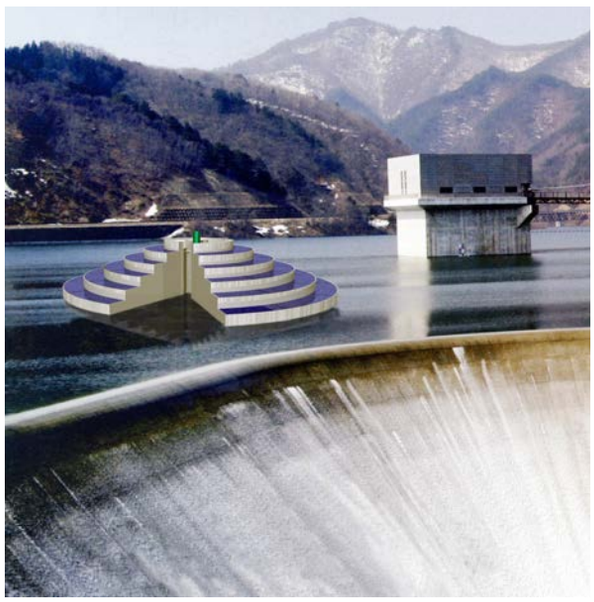


Fig. 15 An example of MU Floating Tower

circulated. In recent years, the quality of water in the river is improving, but the water in a lake and pond is said to be difficult to be improved because the large volume of energy is needed. MU Floating Tower is being developed as an effective device for improving the water quality in a wide area, like lake and pond.

### 4.3 Basic structure of MU Floating Tower

MU Floating Tower is a water purification device embedding compacted MU Aqua Tower or MU Green Reactor into a part of a floating body like a ship. When MU Green Reactor is embedded, double pipes are used to insert into the water, generating water circulation and microbubble by the effect of the airlift.

Fig. 15 shows an example of installation of MU Floating Tower. Since the device can move and float on the surface freely, this can be installed on the closed water like lake and pond easily, and this advantage can evoke further utilization of the device. With the solar/wind power generation device on the top of it, the power can be self-generated for pumping water and air. Realizing this system can build a system of semi-permanent water purification.

### 4.4 Four Types of MU Floating Tower

Fig. 16 shows four types of MU Floating Tower as follows.

1. Aqua Tower Type

Compacted MU Aqua Tower is installed at the center of this device. Water is purified by falling down water from the top of the device by lifting pump and passing through MU Mixing Element. This is suitable for the shallow water.

2. Casing Type

MU Mixing Element is installed in the underwater casing of the center of the device. The device generates microbubbles

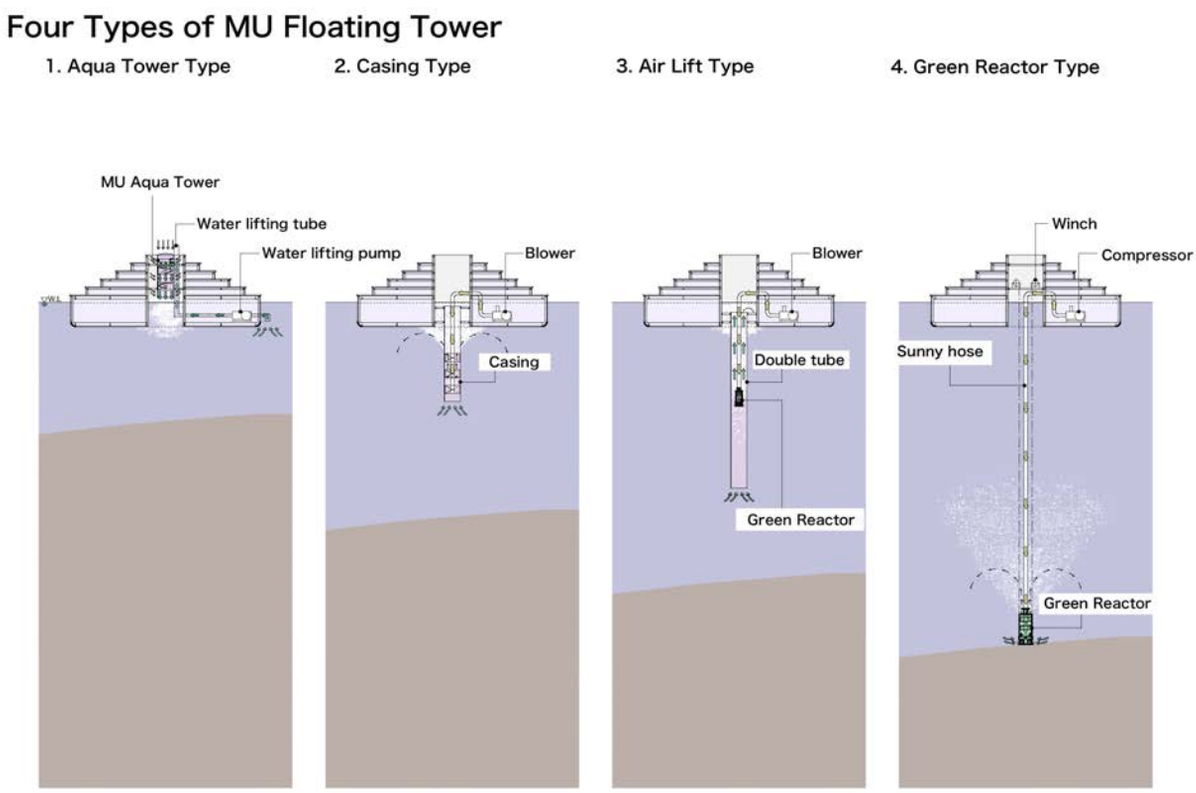



Fig. 16 Type of MU Floating Tower

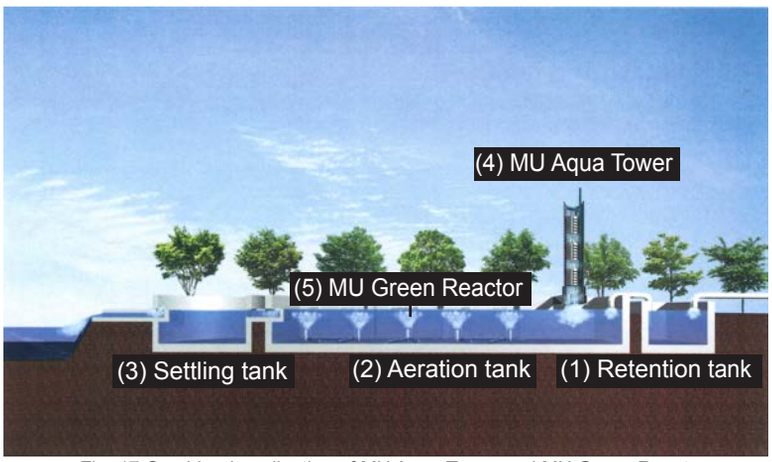


Fig. 17 Combined application of MU Aqua Tower and MU Green Reactor

by blowing the compressed air by a blower from the bottom of the underwater casing. Shallow water is also suitable.

3. Air Lift Type

Air compressed by a blower is sent to MU Green Reactor, installed in a double tube at the center of the device, and the large volume of microbubbles are generated. The deeper water is available for this type.

4. Green Reactor Type

MU Green Reactor is sunk at the bottom of the water using a winch and compressed air is sent to MU Green Reactor by a sunny hose. Since microbubble can be generated from the bottom of the water, a large volume of water can be improved.

### 4.5 Feature of MU Floating Tower

As mentioned above, MU Floating Tower has a potential for a variety of use due to the features, such as mobility, saving-energy, and a variety of types. The Tower also has the advantages of compactness, maintenance free, and friendly to the natural ecosystem. The simple design seems to avoid damaging the scenery of the shore of a lake or pond. It would be grateful if MU Floating Tower would be installed everywhere in the world as a water purification device with permanency which exceeds the human timescale.

### 4.6 Synergetic effect of MU Green Reactor and MU Aqua Tower

MU Green Reactor can generate strong circulation flow and when MU Aqua Tower is used together with MU Green Reactor in the big closed water, the effective increase of dissolved oxygen can be performed (Fig. 17). Fig. 17 contains (1) retention tank, (2) aeration tank and (3) settling tank. In the aeration tank, are (4) MU Aqua Tower and (5) MU Green Reactor installed.When MU Aqua Tower is injected with $O_2$ gas, the tower can be a device for ozone treatment. Likewise, when the tower is injected with air, the tower can be a stripping tower of $NH_3$, $H_2S$.

## 5. Conclusion

With “Why do waterfalls and surge look white?” as an origin of our ideas, we, MU Company Ltd., have forwarded step by step for 35 years to research and develop a variety of devices with the advantages of high efficiency, free-of-maintenance, and saving-energy toward the conservation of the global environment. Though a record track of MU-SSPW in the field of wastewater treatment is not so much, in this paper, we describe how MU-SSPW can be applied to wastewater treatment, explaining the device with the integration of regenerated energy, such as solar and wind power, free-fall energy from the law of waterfalls, potential energy. It will be our sincere desire to make a persistent effort for better products, thinking of the transforming from the horizontal to vertical type of wastewater treatment device, with the notion of reproduction and coexistence.

Now the sea is lull in the wind.

*“Sakura Sakura Waga Shiranui ha Hikari Nagi[*7]” (Michiko Ishimure, “Ten”)*

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*6 https://www.flickr.com/photos/ent108/2184549701/in/gallery-flickr-72157644747506520/ (as of June 30, 2018)
*7 meaning “Sakura, Sakura, on my sea, Shiranui Sea, some glittering on the surface, lull in the wind” The sea was famous for the place of Minamata disease, and used to be polluted by the industrial wastewater and perhaps the sea is glittering due to some chemical pollutant. This poem by Michiko Ishimure gently describes "all life" which return eternally and regenerate circularly, with affection for wonder that all life exist here now, not "human beings" which exist from birth to death linearly.

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