BrightWater Environmental

water purification and sterilisation

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BrightWater Titanium Advanced Oxidation Process (AOP)

an environmentally friendly, chemical-free disinfection and water purification system

Titanium AOP – the water sterilisation system designed to destroy *Legionella* and harmful organisms while preventing the formation of bio-films

WRAS APPROVED PRODUCT

Certificate available on request

Titanium AOP - features and benefits

Titanium AOP is an environmentally friendly 'gatekeeper' solution that prevents *Legionella* and other organisms from entering the water system within the building. Titanium AOP has been installed throughout Europe and Asia in a range of applications including potable water supplies, cooling towers, humidifiers, swimming pools, spas, showers and process water.

- Ensures the non-selective destruction of all organisms quickly and easily, including *Legionella*
- Environmentally friendly
- Cost effective as expensive chemicals are not required
- Eliminates risk of over dosing with chemicals and subsequent corrosion to pipework and valves
- Photo-Catalytic Oxidation and Hydroxyl Radical have the highest oxidation/ Redox value of any disinfection method available for potable water systems
- Photo-Catalytic Oxidation and Hydroxyl Radical decompose organic and microbiological matter, pollutants, hydrocarbons and help prevent biofilms forming
- Offers a water purification process in addition to disinfection system
- Vitens Laboratory test on live cultured *Legionella* grown in Amoebae produced a Log 6 reduction using AOP technology
- Patented Electronic Control Gear reduces power consumption, monitors lamps and overall system performance
- Systems available for flow rates from 1m^3/hour to over 400m^3/hour
- Low energy consumption
- Simple, low cost maintenance procedures
- Proven track record – installed worldwide
- WRAS approved

Titanium AOP - the operating principles

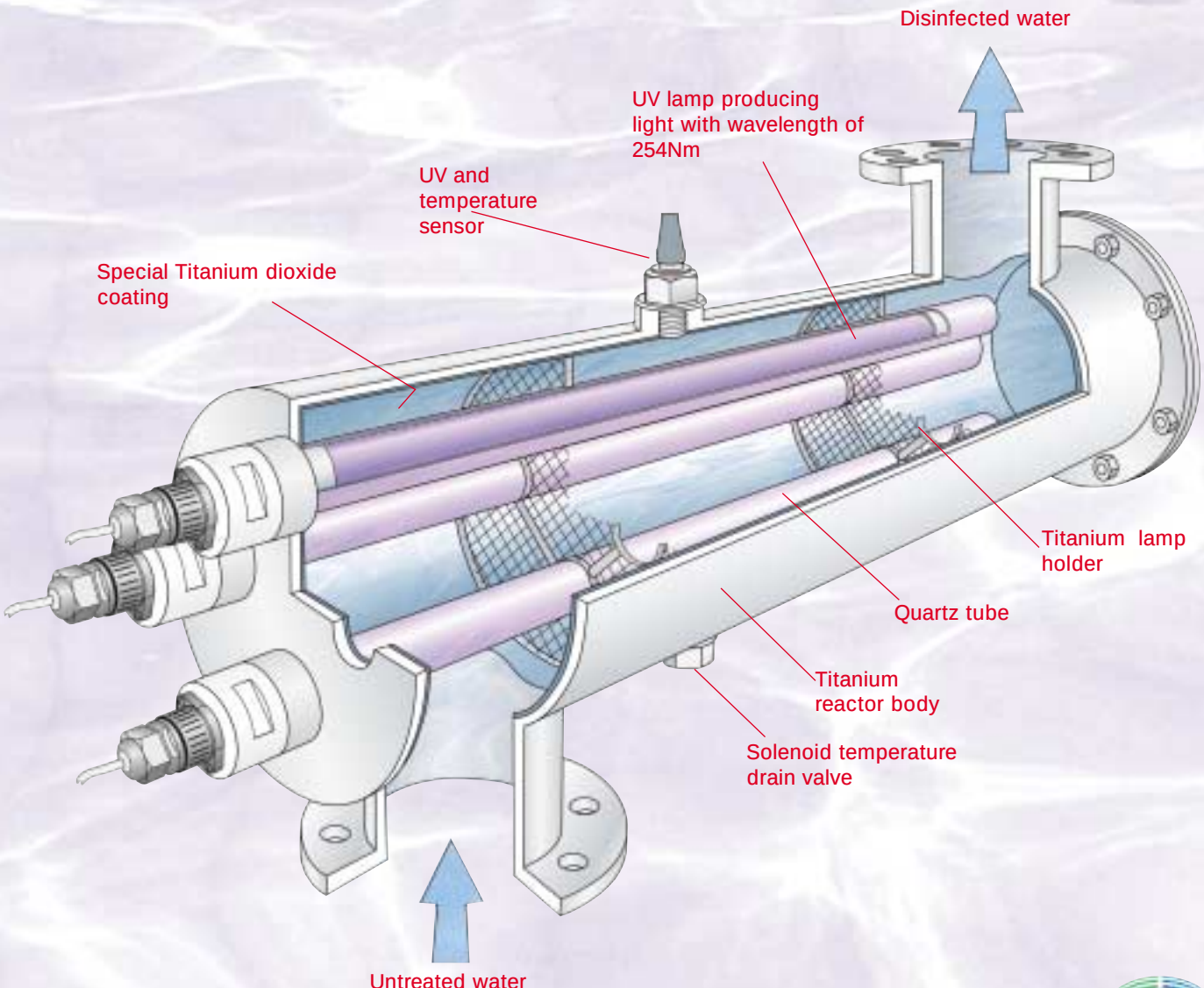
The Advanced Oxidation Process (AOP) that is at the heart of the system has been shown to provide an exceptional capacity to 'kill-all' waterborne organisms as well as to decompose the resulting organic matter. This unselective 'kill-all' technology gives complete oxidation and purification of the water system that represents a watershed in the advancement of water treatment technology.

Until now where high killing rates are needed to achieve good levels of disinfection, unstable high maintenance chemical systems such as Ozone have been used. The alternative is now available through the use of the Titanium AOP system that offers the highest killing rates in a chemical free, low energy, environmentally friendly package that is also simple and cost effective to maintain.

The unique design of the AOP unit produces a two stage reaction process. The first reaction is Photo-Catalytic Oxidation and the second produces a proliferation of Hydroxyl Radicals $OH^{\bullet}$ that are extremely unstable and aggressive. These two processes instantaneously react with micro-organisms and other organic contaminants within the water and literally tear them apart by removing hydrogen atoms from any living organism present within the reactor chamber. This hydrogen extraction and electron transfer completely destroys their cell structure and continues to break down all by-products and pollutants eventually to carbon dioxide.

These reactions occur so quickly that the entire process takes only a few milliseconds before everything reverts back to the stable state of water.

Cross section through Titanium AOP reactor



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Titanium AOP – oxidation strength of Photo-Catalytic Oxidation and Hydroxyl Radicals

The process uses a Titanium vessel with a unique titanium dioxide coating on the internal surface. The AOP exploits the photo-catalytic effect created when UV at 254nm reacts on the Titanium Dioxide coating in the presence of water. This process generates a Photo-Catalytic Oxidation reaction which is stronger than any other common oxidant. This reaction will oxidise and kill any micro-organism and breakdown any organic pollutant present.

The Photo-Catalytic Reaction is so strong that if no pollutants are present it oxidises water to Hydroxyl Radicals. These Hydroxyl Radicals are also very high strength oxidising agents which are mobile and hence destroy those microbes or pollutants present in the main water stream. The Photo-Catalytic reaction in combination with the effect of the Hydroxyl Radicals makes the Titanium AOP the strongest oxidising system available.

To compare the oxidation strength of the two AOP reactions; Photo-Catalytic Oxidation and Hydroxyl Radicals a comparison table can be seen below. The table shows the Reduction Oxidation (Redox) values which is the relative oxidation strength of the common oxidising systems available and clearly demonstrates that none can compare with the Titanium AOP.

Reduction Oxidation Potential

Oxidant	Formula	Oxidation Strength (eV)
Photo-Catalytic Oxidation	TiO_2 + (UV at 254nm)	3.21
Fluorine	F_2	2.87
Hydroxyl Radical	$OH^{\bullet}$	2.8
Singlet oxygen	O ($_1$D)	2.42
Ozone	O_3	2.07
Hydrogen peroxide	H_2O_2	1.78
Permanganate	MnO_4	1.67
Hypochlorous acid	HOCl	1.48
Monochloramine	NH_2Cl	1.4
Chlorine	Cl_2	1.36
Hypobromous acid	HOBr	1.33
Oxygen	O_2	1.23
Bromide	Br_2	1.07
Chlorine dioxide	ClO_2	0.95

Testing

To validate the Advanced Oxidation Process the system was tested in 2008 to KIWA guidelines at the Vitens Laboratory in The Netherlands using concentrations of *Legionella* that were many times more than it would be possible to encounter outside of Laboratory conditions.

The testing protocol used live cultured *Legionella Pneumophila* that was specially cultivated in live Amoebae in order to create the most extreme conditions to test the killing of bacteria. The concentration of *Legionella* used was 124,000,000 cfu/litre but due to the cultivation method used there was also 106,000,000 cfu/l of other bacteria present in the testing inoculum. A log reduction of 6 in the number of *Legionella Pneumophila* bacteria was achieved, the highest possible reading, while the other bacteria were also substantially removed. Previously these bacteria had been in competition with the *Legionella* which means that the *Legionella* bacteria could be removed more efficiently when other contaminants are not present. A summary highlight from the report is detailed below.

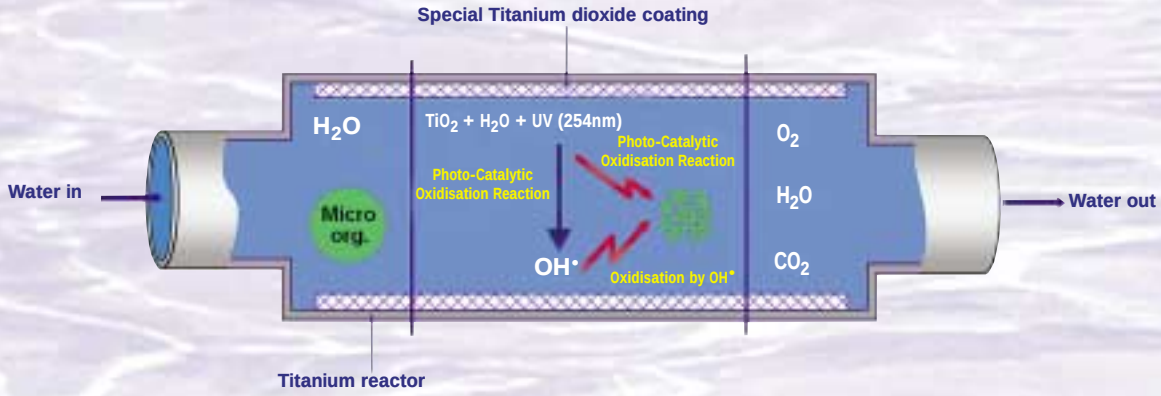
Results obtained from testing Titanium AOP5 at the Vitens Laboratory in The Netherlands

Flow L/min	Time (s) after start	Number of *Legionella* after AOP cfu/l	Average log reduction
20	60	<50	>6.4
40	60	<50	>6.4
60	60	<50	6.4
80	60	400	5.2

Titanium AOP has been tested and approved by WRAS for use in potable water systems in the UK.

Titanium AOP – the chemistry at work

The Titanium AOP System is a physical process that works by exploiting the photo-catalytic effect created when high energy Ultra Violet UV light (at 254nm) strikes Titanium Dioxide(TiO_2) in the presence of water. The high energy UV excites the surface of the TiO_2 at the water interface resulting in a Photo-Catalytic Oxidation reaction. This oxidising reaction is one of the strongest known and is at the heart of the Titanium AOP unit.



The Photo-Catalytic oxidation reaction has two effects. Primarily it will oxidise and destroy any microbe or pollutant present where the reaction occurs. In the case of the Titanium AOP this is the entire surface area of the reactor that is contact with the water. The second reaction oxidises water to generate a proliferation of Hydroxyl Radicals that in turn will also oxidise any microbe or pollutant present.

We can break down these two key Oxidising reactions as follows:

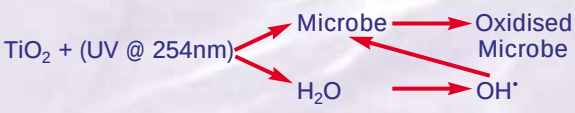
Step One (Reaction 1): Photo-Catalytic Oxidation

This occurs at the surface when UV at 254nm hits and excites TiO_2 in the presence of water. This reaction has two effects:

i) It will oxidise (and therefore destroy) any pollutant present at the reactor surface living (i.e. microbe) or non-living (i.e. pesticide).

ii) Oxidise water to Hydroxyl Radicals $OH^•$. The benefit of creating these Hydroxyl Radicals $OH^•$ is detailed in step 2 below.

Photo-Catalytic Oxidation =

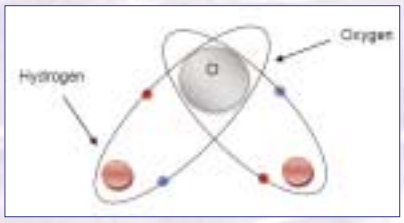


Step Two (Reaction 2): Oxidation by Hydroxyl Radicals

The Hydroxyl Radicals generated as a result of reaction one are dispersed throughout the reactors water chamber due to them being extremely mobile.
The Hydroxyl Radical has very high oxidation strength, a short life and is very reactive.

Due to the large contact area between the water and the reactor surface a proliferation of $OH^•$ Radicals are produced.

What is a Hydroxyl Radical?



Water
H_2O

Hydroxyl Radical
$OH^•$

In essence it is a water molecule with a hydrogen atom removed.

$H_2O \longrightarrow OH^• + H^+ + e^-$

They contain an unpaired electron which makes them very reactive and highly unstable. Due to their extreme reactivity Hydroxyl Radicals only exist for milliseconds before reverting back to water. They are exceptionally strong oxidising agents and oxidise any micro-organism or organic pollutant indiscriminately.

Summary

Due to the short life of both reactions the process takes place entirely within the AOP reactor. The AOP oxidises all organic material living or dead to Carbon Dioxide (CO_2), Oxygen (O_2) and Water (H_2O). Other than destroying such pollutants the Titanium AOP has no effect on the basic water chemistry. The process is truly catalytic as the TiO_2 is not sacrificed or consumed and therefore the AOP reactor carries a lifetime warranty.

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Titanium AOP - applications

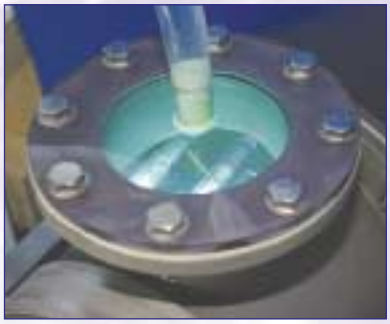
- Swimming pools
- Spas
- Potable water
- *Legionella* control
- Pseudomonas – closed system protection
- Cooling towers
- Humidifiers
- Recycling of grey water
- Rainwater harvesting
- Bore hole water disinfection
- Process applications – food & beverage industry

The Titanium AOP leaves no residual by-products behind. In addition, it not only breaks down *Legionella* bacteria, but also E. coli, Pseudomonas aeruginosa, fungi and all other micro-organisms, but also decomposes any resultant matter, both organic or microbiological. The decomposition of all matter within the AOP system helps prevent biofilms developing as they are starved of the nutrients they require to multiply.

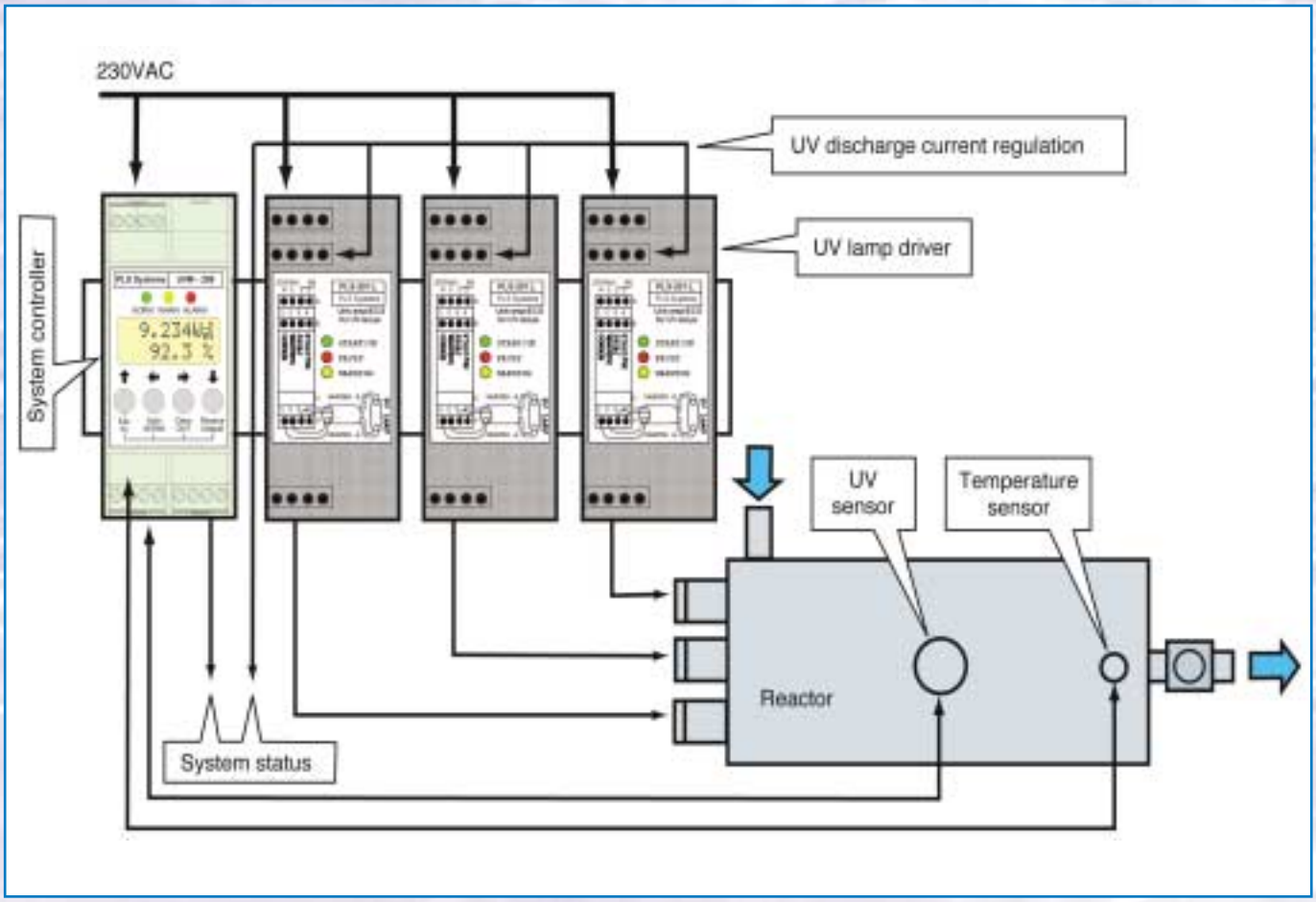
The payback period on the Titanium AOP depends on what sort of methods you are currently using to prevent *Legionella*. You will save the cost of having to raise the water temperatures at regular intervals and then flush through the system. You will also save the cost and environmental impact from no longer needing to purchase chemicals on a regular basis.

In a recent long term test undertaken in Southern Europe the AOP system was fitted on the cooling towers of a large hospital. Prior to this a cocktail of biocide chemicals had been used; all of which had failed to keep bacterial counts low. Environmental conditions at the site were very difficult and included hard water, elevated temperatures, air pollution and high levels of dust. However after only 2 weeks with the AOP in operation the chemical biocide dosing was stopped and bacterial counts were reduced by 99% compared to when the biocide treatment system had been used.

Typical Titanium AOP installations



Titanium AOP - patented electronic controls system



The patented Electronic Control Gear (ECG) is fitted with the most advanced controls to look after the performance of the Titanium AOP system.

The traditional control system for UV units normally involves the use of a single controller that monitors the whole system's performance. In contrast the Titanium AOP system is fitted with an independent controller for each operational part. There is one controller for each individual lamp within the system and another separate controller for the UV Monitor. This ensures a faster and simpler diagnosis of the system should it go into alarm. There is also an added benefit in that each aspect of the AOP's performance can be individually checked and monitored to ensure they are operating at maximum efficiency.

Each control module is individually mounted in a bespoke busbar cabinet on a DIN-35 rail assembly. There will be one control module for each lamp and a final module that is the system monitor. This checks both the UV intensity and the water temperature. Should the intensity of the UV drop the system will go into alarm and if the temperature increases beyond pre – determined parameters the drain solenoid valve fitted to the reactor body will be operated. This will allow fresh cooler water to be introduced into the reactor vessel and is a further safeguard to ensure no over-heating of the system.

The operational status of the system can be checked remotely with a fault contact output from the UV monitor and system controller as shown.

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Titanium AOP - UV monitor, system controller and cabinets

UV monitor

UV Monitor is fully programmable with an LED display. All parameters can be changed using the built-in programming menu. The UV Monitor is factory set and as such is suited to most applications. Measurements taken are of UV intensity at the reactor face and the water temperature. The system has a light display that indicates Normal, Warning and Alarm parameters with detailed information shown in the digital display. The system operates a solenoid dump valve fitted to the AOP system to insure reactor water temperatures are kept below 50ºC and has an output to enable the operational status to be seen remotely.

UV lamp control

UV Lamp Controller is fully programmable with a light display that indicates Normal, Warning and Alarm parameters. It is designed to operate a single lamp and comes factory set and as such is suited to most applications. It has an output to enable the operational status to seen remotely.

The UV Lamp Controller has a number of innovative features that include a programmable lamp pre-heating profile that insures initial lamp current is carefully controlled to give a ‘mild lamp start-up’. To further maximise lamp life the controller reacts to the lamp filament’s resistance to give a soft heating function.

Control cabinets

The dimensions of the control cabinets are set out below

	AOP1	AOP5	AOP10	AOP20	AOP50	AOP100	AOP400
Height	300mm	300mm	300mm	800mm	800mm	1200mm	1900mm
Width	400mm	400mm	500mm	600mm	600mm	600mm	1300mm
Depth	210mm	210mm	210mm	300mm	300mm	600mm	600mm

Titanium AOP - questions and answers

How effective is Titanium AOP at disinfecting water compared to other disinfecting systems?

It has the highest oxidation value of any oxidant and 3 times the oxidisation value of chlorine dioxide. Tests carried out by the Vitens Laboratory achieved the highest log reductions in bacteria.

How effective is Titanium AOP on the various different types of bacteria virus and organisms found in water?

The use of Photo-Catalytic Oxidation and Hydroxyl Radicals is a unique killing mechanism that kills all species of organism equally well. Furthermore by breaking down pollutants and organic matter it delivers purer water and has a European wide reputation as both a water purifier and disinfector.

What are the environmental benefits of fitting an AOP system?

- No chemicals are added to the water which reduces the risk of corrosion to pipework and valves.
- No storage and handling of chemicals on site and the associated COSHH requirements.
- Reduced maintenance and servicing requirements.
- Fail safe controls.
- Full WRAS approval for drinking water supplies.
- Low power consumption.

How can I be sure all the water passing through the AOP system is fully disinfected?

The system design incorporates a unique fully patented control system that has an individual control monitor for each UV Lamp. Each lamp has a warning that operates as soon as an individual lamp has a low UV intensity. It will then go into a state of alarm when intensity reduces further. As a second safeguard there is an overall system monitor that continually reads the intensity of the UV lamps at the reactor surface. This monitor operates with an additional warning and alarm display. If any of these warnings or alarms are activated or if power is switched off a signal can be sent to a remote monitoring panel.

What flow rates can be treated with a Titanium AOP system?

There are 7 units in the range that cover flow rates from 0.28 L/s up to 111 L/s .For higher flow rates units may be fitted in parallel.

Where should the Titanium system be installed?

Location is application specific. On commercial buildings the system is commonly fitted to the cold water mains to treat the entire water supply and thereby offering protection to the whole building's water system particularly from *Pseudomonas* and *Legionella* bacteria.

What can I expect the Titanium AOP system to achieve that is different to a UV system?

Both systems disinfect the water in a safe and efficient way that is chemical free. The main differentiator is that the AOP gives a superior level of disinfection than either UV or chemical systems. The level of disinfection from using AOP results in organic matter and pollutants in the water being broken down to produce a much purer quality of water.

How long has the technology been used for disinfecting water?

The first testing of UV light with Titanium Dioxide for disinfection of fluids was carried out in the 1970s with the first commercially available Titanium AOP units being installed in 2002. Since then the Titanium AOP system has been installed worldwide including Sweden,Spain, Italy, Germany, France, Poland, China, Australia, the Middle East, America and the UK.

Is the AOP system suitable for drinking water and will the taste be altered in any way?

The system is well suited to drinking water supplies where it is important that the water is both bacteria free and of good taste. The system is chemical free and therefore does not alter the taste in any way. The breaking down of organic matter, microbiological material, water pollutants and pesticides that are present in water will make the water safer, purer and taste better. The system has also been tested and approved by WRAS (The Water Regulatory Advisory Scheme).

Is the AOP system suitable for other non-potable water treatment applications?

Yes the AOP system has many applications for disinfecting water these include heating & chilled water system protection from *Pseudomonas* bacteria, cooling tower water treatment, humidifiers, bore hole water disinfection, rainwater harvesting, disinfection of process and manufacturing water supplies, food & beverage disinfection and hospital sterilisation.

What are the service and maintenance requirements for the AOP system?

Provided that good quality water is passing through the AOP system it will only require annual servicing. The UV lamps will need to be replaced annually and cost will therefore depend upon the size of the unit and hence the required number of UV lamps. If the water has high metallic content, contains high amounts of calcium carbonate or is at a high temperature the quartz tubes housing the UV lamps may need to be cleaned more frequently than just the annual service. Outside of the service cost power is also required to run the UV lamps.

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Titanium AOP model range

Model	AOP 1	AOP 5	AOP 10	AOP 20	AOP 50	AOP 100	AOP 400
Throughput							
Maximum flow (L/sec)	0.30	1.40	2.80	5.5	13.9	27.7	111.1
Maximum flow (m^3/hr)	1	5	10	20	50	100	400
Water pressure drop (bar)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Electrical specifications							
Voltage (V)*	230	230	230	230	230	230	400
Power consumption (W)	26	100	200	380	700	1300	4930
Fuse rating (A)	3	3	3	3	5	13	3x10
Number of lamps	1	1	2	4	7	13	46
Dimensions							
Diameter x length (mm)	74x475	75x895	120x890	160x960	225x955	305x955	606x979
Material	Titanium	Titanium	Titanium	Titanium	Titanium	Titanium	Titanium
Thread connection (BSP)	DN 15	DN 40	DN 50	DN 100	DN 125	DN 150	DN 300
Supervised features							
Continuous monitoring of UV radiation	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control of lamp life time	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Preheating of cathodes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Information about alarms	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Soft start	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Measurement of UV radiation intensity	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Soft heating function	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Failure indications	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Remote monitoring of system	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Measurement of water temperature in the reactor	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Solenoid drain valve water temperature control	Yes	Yes	Yes	Yes	Yes	Yes	Yes

*110V units available on request

The Titanium AOP is made up of a small number of components and has no moving parts. This makes it reliable, quick and easy to install.

It is easy to configure the Titanium AOP to meet purification needs, water flows and available space. The range includes 7 models that may be installed either vertically or horizontally and have the capability to treat flows from 0.1 litre/second up to 111 litres/second. For higher flow situations units may be fitted and used in parallel.

The Titanium AOP's control unit includes an alarm function, which can be connected to a Building Management System (BMS) for example, to indicate when a lamp requires changing.

In waterborne pipe systems there is a possibility that the piping will degrade, giving rise to many types of internal surface damage, anomalies, corrosion and, where design changes have occurred, potentially dangerous so called 'dead legs' or 'dead ends'.

The environment in a piping system, irrespective of piping material, may thus be such that *Legionella* and other micro-organisms are present, and, as a result, there is a possibility that *Legionella* and other micro-organisms may continue to exist in the system even after installation and operation of Titanium AOP.

Given the possibilities for *Legionella* and other micro-organisms to continue to exist in any waterborne system, BrightWater Environmental Ltd do not accept any liability whatsoever for damages caused by the existence of *Legionella* and other micro-organisms in waterborne systems where Titanium AOP is installed.

Specifying Titanium AOP

- The water purification and disinfection unit shall break down and destroy all waterborne organism, to include fungi, yeast, amoebae and viruses by the use of Hydroxyl Radicals.
- The purification and disinfection process will take place by means of an Advanced Oxidation Process.
- Photo-Catalytic Oxidation will be created by photonic energy at wave-lengths of 254nm and Titanium Dioxide that will generate Hydroxyl Radicals.
- The body of the unit shall be of Titanium construction with a Titanium Dioxide Crystal coating applied to the internal surfaces of the reactor body to maximise the Photo-Catalytic reaction creating Hydroxyl Radicals.
- The Photo-Catalytic Oxidation shall have a Redox Potential of 3.21 and the Hydroxyl Radicals a Redox Potential of 2.8 to ensure complete oxidation of all waterborne organisms and organic matter
- No additives shall be used in the process and no harmful residuals shall be formed.
- The unit shall have a control system that will include facilities for a remote control system, failure indications, UV intensity monitor, water temperature measurement, mild start function and soft heating function.
- Water purification and disinfection units shall be Titanium AOP from BrightWater Environmental Ltd or equal and approved subject to a technical submittal demonstrating compliance with the above criteria.

Skanska were keen to implement the environmentally friendly Titanium AOP system at the Royal London Hospital where innovation and utilising new ideas are part of the hospitals core values. The two AOP 50 units shown have been installed in parallel to provide the level of treatment required by Skanska in a demanding and prestigious hospital environment.

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Titanium AOP - treating water around the world!

AOP5 fitted to a cooling tower at Kent County Council removing the need for biocide chemicals.

AOP100s fitted in a skid for installation on cooling towers at a nuclear facility.

Two AOP100's treating process water at an electronics manufacturer in China.

AOP20 used for sterilisation of drinking water at a treatment works in Poland.

AOP5 fitted to the rain water harvesting system at Polypipe Terrain training centre in Kent.

AOP20 fitted to cooling towers at the National Valencia Hospital, Spain, replacing biocide chemicals.

AOP100 treating process water at an automotive parts manufacturer in Sweden.

AOP50 installed onto the cold water mains supply to a London prison.

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